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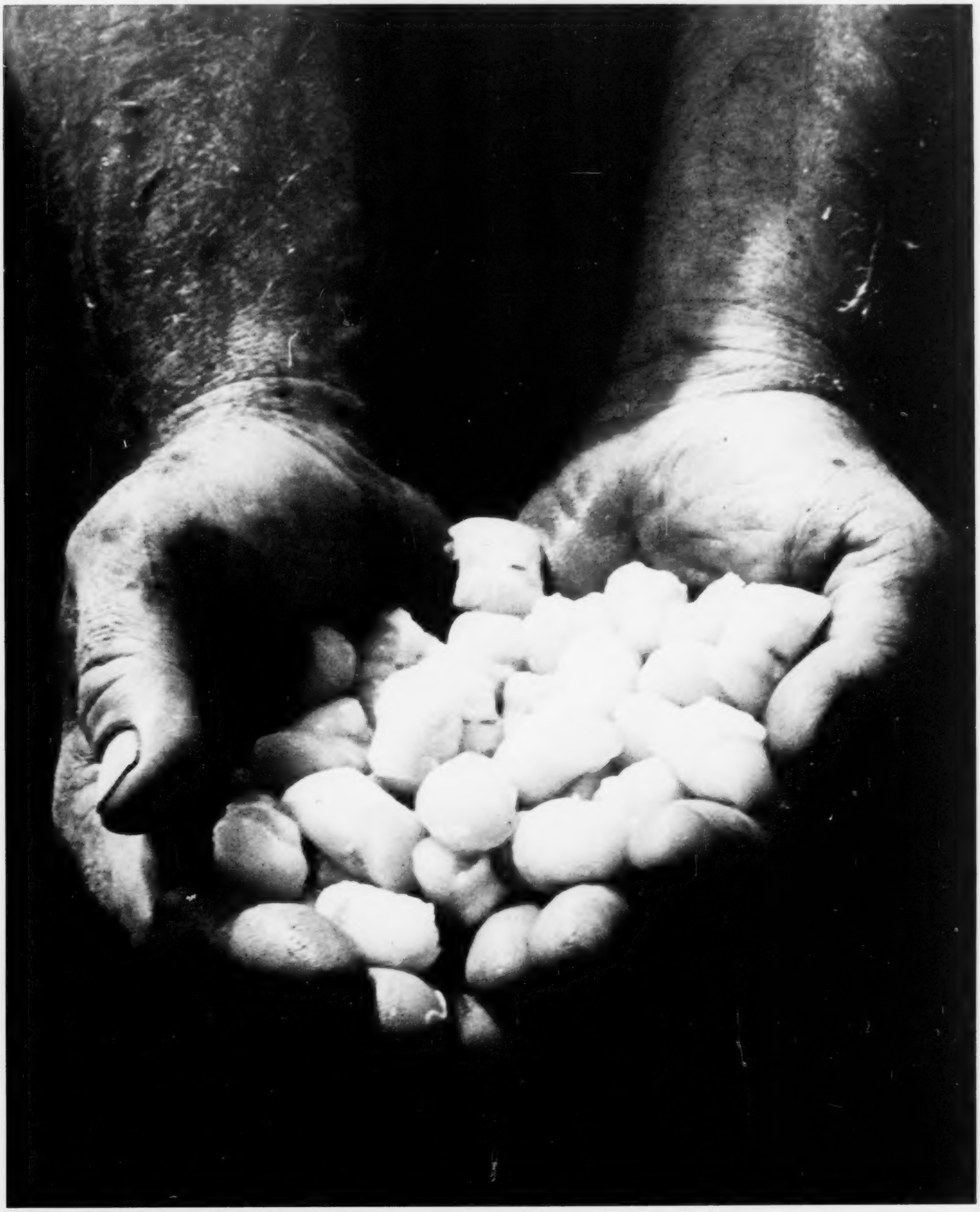

Marine Fisheries Review

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National Marine Fisheries Service

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MFR PAPER 1352

Scallops and Their Utilization

Calico scallops dredged off Florida's east coast. Photograph by the Florida State News Bureau, Tallahassee.

JOHN A. PETERS

INTRODUCTION

This paper brings together pertinent information on the history, biology, harvesting, and utilization of the various species of scallops of commercial importance in the United States. The information is contained in almost 200 papers covering a span of about 100 years.

HISTORY

There are currently four species of scallops of commercial importance in the United States: Sea scallops (*Placopecten magellanicus*), bay scallops (*Aequipecten irradians*), calico scallops (*Argopecten gibbus*), and the Pacific sea or weathervane scallop (*Patinopecten caurinus*).

Sea Scallops

The sea scallop fishery began on a small scale about 1880 when some of the inshore beds along the New England coast were fished. By 1900, landings were about 400,000 pounds (180,000 kg) of meats with the largest volume being landed in Maine ports. Then, in the early 1920's, scallop beds were discovered off along Long Island and the fishery shifted to that area. With the discovery of sea scallops on Georges Bank, the major activity shifted north with New Bedford evolving as the major scallop port in the United States, a position it has held ever since.

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A relative lack of abundance of scallops on Georges Bank in 1965 led to the exploitation of sea scallop populations from Hudson Canyon off New Jersey south to Cape Hatteras. This bonanza was short lived, and mid-Atlantic landings returned in a few years to somewhat less than their previous levels. At the same time, landings in Virginia ports increased greatly from 194,000 pounds (88,000 kg) of meats in 1964 to 2.8 million pounds (1.3 million kg) in 1965. Regional trends in sea scallop landings from 1960 to 1974 are presented in Figure 1.

In 1976, total landings of sea scallop meats were 20,000,000 pounds (9,000,000 kg) worth $35,000,000 to the fishermen or $1.77/pound ($3.90/kg) making the sea scallop the tenth most valuable fishery product in the United States and the second most valuable bivalve, with oysters ranking first (O'Brien, 1961; Bourne, 1964; Robinson, 1977).

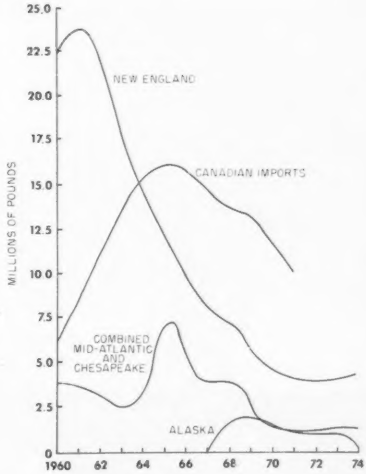


Figure 1.—Sea scallop landings, imports, in various regions. Source: Fisheries of the United States, Curr. Fish. Stat., Natl. Mar. Fish. Serv., NOAA, various numbers and years.

Bay Scallops

Bay scallops have been harvested since colonial times when settlers on Cape Cod picked them up by hand at low tide (Belding, 1910). Landings of bay scallops fluctuate widely from year to year reflecting the relative success or failure of a particular year class. As bay scallops live somewhat less than 2 years, spawning success is reflected very quickly in the catch rate (characteristic of all short-lived species). For

instance, in 1968, landings of bay scallop meats in New England were less than 500,000 pounds (227,000 kg). According to Hanks (1971), landings had jumped to over 2,000,000 pounds (900,000 kg) in 1971, but then they dropped equally rapidly to about 550,000 pounds (250,000 kg) in 1974; and, in 1976, total United States landings of bay scallop meats were again over 2,000,000 pounds (900,000 kg).

Calico Scallops

Calico scallops have been harvested only since 1960 when the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) discovered the beds off Cape Kennedy, Fla. Landings from these beds and from those off North Carolina and northwestern Florida have fluctuated widely as is common with short-lived species. In recent years, landings went from a low of 558,000 pounds (250,000 kg) worth $356,000 in 1973 to over 2 million pounds (900,000 kg) worth about $1.4 million in 1976. The most consistent production has been from the Cape Kennedy beds with very little recent production from off North Carolina and none from northwest Florida (Robinson, 1977; Allen and Costello, 1972; and Cummins, 1971).

Figure 2.—The sea scallop, *Placopecten magellanicus*.

Pacific Sea Scallops

For serveral years in the 1960's, there was considerable interest in developing a fishery for the Pacific sea (weathervane) scallop. Several New Bedford vessels went to the west coast to help establish the fishery. However, problems with production, processing, and marketing somewhat dimmed the initial enthusiasm which had led to an article in the trade press entitled "U.S. Scallop Fishery—Switching Coasts?" (Anonymous, 1968). As of 1974, landings of scallop meats in Alaska amounted to about 7 percent of the volume and 7 percent of the value of all scallops landed in the United States. For statistical purposes, the landings data are included in the landings of *Placopecten magellanicus* (Anonymous, 1968; Bell and Fitzgibbon, 1977).

Figure 3.—Sea scallop engulfed by starfish; other sea scallops nearby.

BIOLOGY

Biologically speaking, scallops are benthic marine pelecypod mollusks of the family Pectinidae.

Sea Scallops

The sea scallop (Fig. 2, 3) is one of the largest of the family Pectinidae in the United States. It commonly grows to 6-7 inches (150-175 mm) in diameter, and individuals as large as 9 inches (200 mm) are not uncommon. The bottom shell is fairly flat and usually white in color; whereas, the upper is somewhat convex and reddish brown. A striking feature of all scallops is the rows of functioning bright blue eyes along the edges of the mantle. Another unique feature of the scallops is their ability to swim which is maintained throughout their life. The swimming ability varies with species, with sea and bay scallops being particularly adept.

The scallops swim by jet propulsion. Water is taken into the mantle cavity and then forcefully expelled in several ways which make it possible for the animal to move in any one of several directions. By expelling the water through openings on either side of the hinge, the scallop moves with eyes front. Water can also be expelled at the forward edge of the shell driving the scallop backward (hinge first). Finally, either of the two hinge jets may be used to provide a spinning motion.

The sexes of the sea scallop are usually separate, but hermaphrodites are found occasionally. Spawning occurs in late summer or early fall. Exact time varies from one year to the next and from one area to another. What triggers spawning is not known precisely, but it probably is temperature related. The fertilized eggs remain on the bottom for the first stages of life. They soon become free swimming but still tend to stay close to the bottom. The free swimming stage lasts about 2 weeks, varying with water temperature. When they settle to the bottom, the scallops attach themselves to various substrates by means of byssal threads. The ani-

mals can (and frequently do) sever their thread connection and swim in apparently random directions for considerable distances—well over 100 feet (30 m) is apparently not uncommon. At a shell diameter of about 3 inches (75 mm), the scallops lose the habit of byssal attachment but still retain, to a lesser degree, their swimming ability.

Sea scallops require about 4½ years to reach the 3¾-inch (95-mm) size recommended by the International Commission for the Northwest Atlantic Fisheries and proposed as a regulation by the National Marine Fisheries Service as the minimum that should be harvested to insure a sustainable yield (Bourne, 1964; Posgay, 1950, 1953).

Figure 4.—Bay scallop meats.

Bay Scallops

Bay scallops occur from New England to the Gulf Coast of Florida. In contrast to the sea scallops, they are small, rarely exceeding 3 inches (75 mm) in height with the maximum being 3½ inches (90 mm) (Fig. 4). The shells are equally curved and prominently ridged. They are thin in proportion to size so the bay scallop remains an active swimmer during its short life span.

Bay scallops are hermaphroditic (both male and female sex organs are found in each individual), but usually only one kind of sex cell is cast out at any one time. Spawning occurs from mid-June to mid-August when the scallops are about 1 year old; very few spawn twice. The young are free swimming for about 12 days at which time they attach themselves by means of their byssal threads to various substrates. The bay scallop maintains its attaching ability throughout its 20-26 month life span.

During the winter, bay scallops grow only very slowly; as a result, a fairly thick ridge or line appears on the shell. It is the presence of this ridge that unfailingly distinguishes the adult from the juvenile. In most areas, it is forbidden to harvest bay scallops lacking the ridge. Also, in many areas, harvesting is prohibited entirely from a few months before to a few months after the peak spawning period. In general, the "open season" is from 1 October to 1 April (Belding, 1910; Gutsell, 1931).

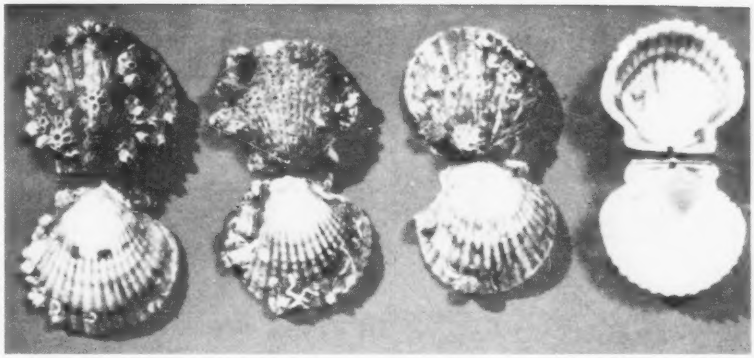


Figure 5.—Calico scallops.

Calico Scallops

The calico scallop is found from Cape Hatteras along the shores of the Gulf of Mexico, throughout the Greater Antilles, and around Bermuda. They are somewhat smaller than the bay scallop, generally growing to 1½-2¼ inches (40-60 mm) with the maximum about 3⅛ inches (80 mm) (Fig. 5). The shells are about equally convex, deeply ridged, and are mottled with red to brownish-red bands on a light background. The shells are considerably thicker than those of the bay scallop which accounts for the fact that, although smaller, the calico scallop is less motile.

Like the bay scallop, the calico scallop is hermaphroditic. In the laboratory, it has been observed that when spawning, the sperm is ejected first followed by the eggs. Spawning of the calico scallops is related to age rather than size; that is, all calico scallops 10-12 months old will spawn regardless of the size they may have reached.

Spawning is, as with other species, probably triggered by rising water temperatures as it begins about the first of March and continues to June and occasionally longer. A drop in temperature during spawning will cause it to terminate.

The larvae are planktonic and may be found anywhere from the surface to the bottom. The small calico scallops, like the bay scallops, attach themselves by byssal threads to various objects, such as any shell material, pieces of tile, rope, etc. Although the attaching is greatest in the young scallops, of less than 1 inch (25 mm), the ability is maintained but rarely used for the life span of the species.

The duration of the plankton stage from fertilization to settling on the bottom is about 2 weeks. At this time, the young are only 0.01 inch (0.25 mm) in shell height; but, in 10 weeks, they have grown to over 1 inch (25 mm); and it is estimated that in 24 months, the maximum age, the scallops average slightly over 2 inches (54 mm) (Allen and Costello, 1972).

Pacific Sea Scallop

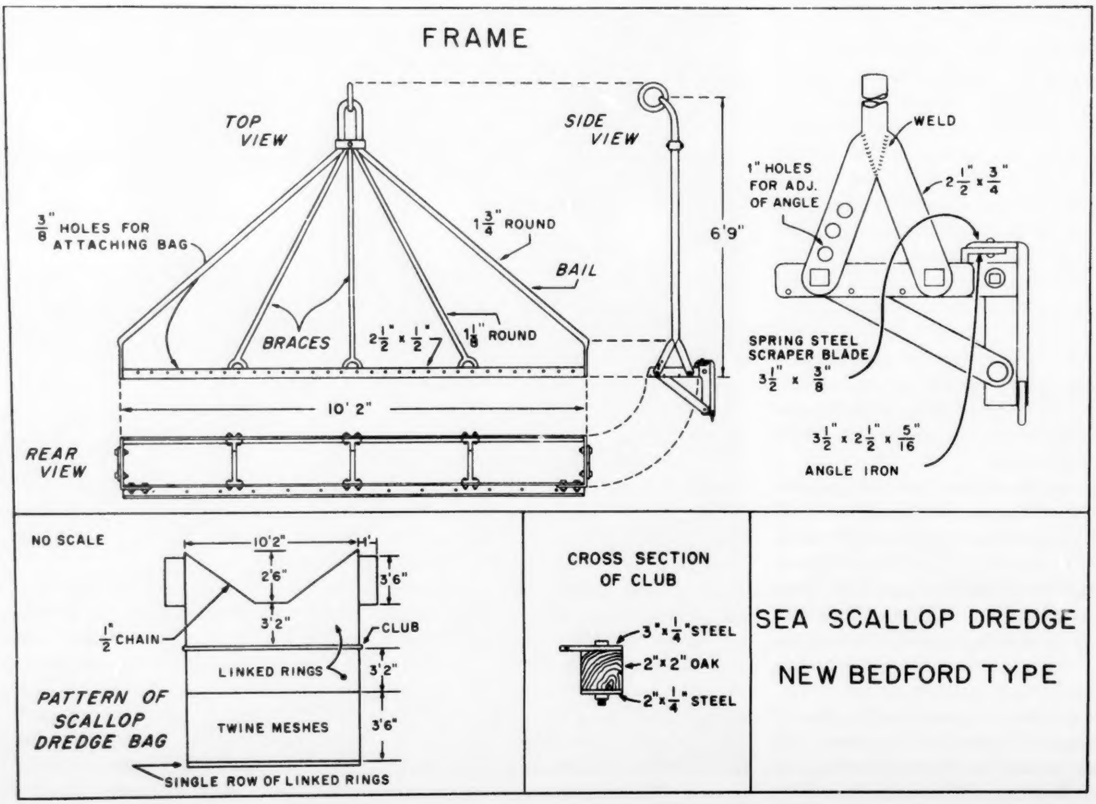
Information on the spawning, growth, and reproduction of the Pacific sea scallop is very fragmentary. However, spawning appears to occur during the summer. Growth rate varies greatly with area, being 1.5 times greater on some beds than on others. In most respects, the Pacific sea scallop seems to be very similar to the east coast sea scallop (Haynes and Hitz, 1971).

HARVESTING

Sea Scallops

Until recently, sea scallops have been caught almost entirely by dredges (Fig. 6). Vessels up to about 100 feet (30 m) tow two dredges simultaneously, one from each side of the vessel. The dredges may be as much as 14 feet (4.25 m) wide, but 11-12 feet (3.35-3.7 m) is more common. In the last few years, however, there has been a trend toward using conventional otter trawls modified by adding sweep chains and chafing gear to protect the net from the bottom. The otter trawls are used primarily on the smooth hard bottom found in the scallop beds off the mid- and South Atlantic areas. In the first half of 1976, about half the scallops

Figure 6.—New Bedford-type sea scallop dredge.



landed in Virginia were caught by otter trawl. Most of Georges Bank, however, is too rough for otter trawls. (Kelly, 1976[1]).

The sea scallop dredge consists essentially of a rectangular frame 11-14 feet (3.35 -4.25 m) wide by about 1.5 feet (0.5 m) high. The lower frame assembly is a spring steel scraper blade which serves to scoop the scallops up and into the linked ring bag. The steel rings which make up all of the bottom and about half of the top are usually 3 inches (75 mm) in inside diameter made from $^{5}/_{16}$-inch (9½-mm) stock held together with dredge clips. The forward half of the top is made up of $^{5}/_{16}$-inch (9½-mm) cord fastened into 6-inch (150-mm) stretched mesh netting by means of cord clips (Bourne, 1964; Royce, 1947; Posgay, 1957).

[1]William Kelly, Supervisory Fishery Reporting Specialist, Statistics Branch, National Marine Fisheries Service, NOAA, Brittingham Bldg., 55-57 W. Queen Street, P.O. Box 447, Hampton, VA 23669. Pers. commun.

Bay Scallops

Bay scallops are usually caught with small dredges towed by outboard motor boats. In shallow waters, they may also be taken with dip nets, rakes, or even picked up by hand.

The bay scallop dredge is only about 3 feet (1 m) wide. The bag is made up of 2-inch (50-mm) inside diameter rings on the bottom and 2-inch (50-mm) mesh netting of heavy twine on top (Schwind, 1976).

Calico Scallops

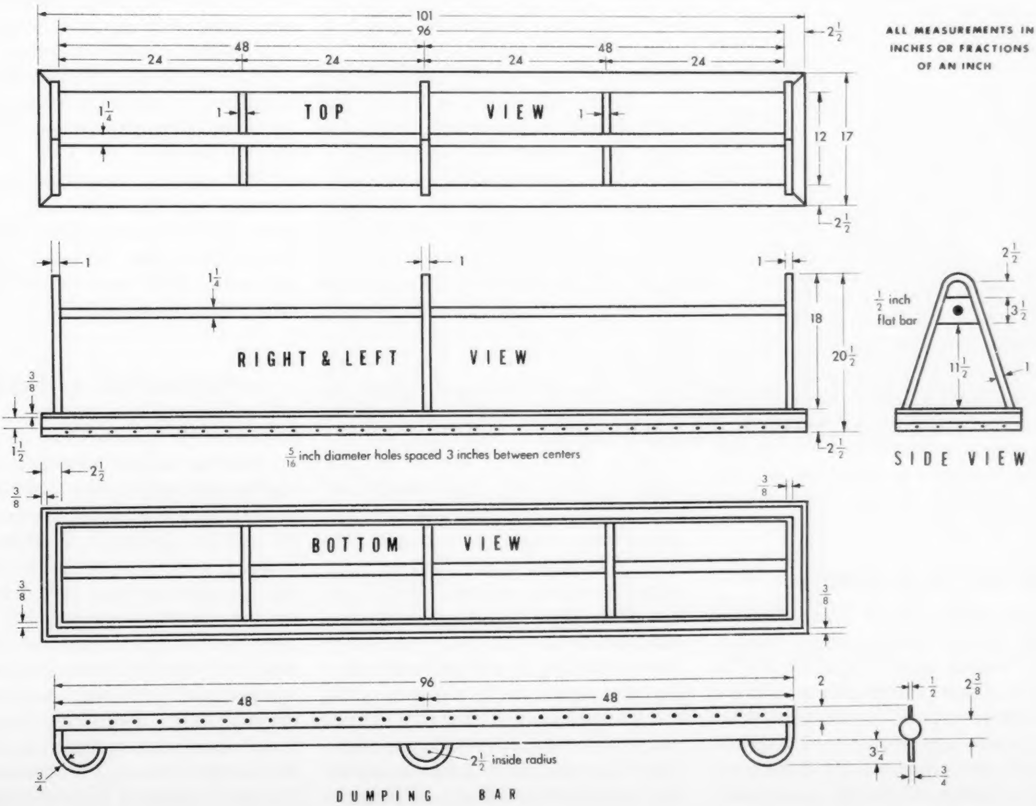
This species is caught either by tumbler dredge (which will fish either side up) or by modified otter trawls. The type of bottom dictates the gear to be used.

The calico scallop dredge (Fig. 7) has a rectangular frame opening identical on top and bottom edges, the bag is made up of 2-inch (50-mm) inside diameter rings held together with clips (Rivers, 1962; Bullis and Cummins, 1961).

PROCESSING

Primary processing (removing the meat from the shell) may be done at sea or ashore. Historically, the vast majority of sea scallops was shucked aboard the vessel. Recently, there has been a

Figure 7.—Calico scallop dredge.



trend toward shucking ashore. Bay scallops are almost always shucked ashore, and calico scallops have been shucked both aboard (Fig. 8) and ashore.

The yields of meats obtained vary with location of the beds and the time of year, being less after spawning. Average yields per U.S. standard bushel, which weighs from about 70 to occasionally as high as 80 pounds (32 to 36 kg), are reported as: 6 pounds (2.7 kg) for sea and bay scallops and 2.7-3.5 pounds (1.2-1.4 kg) for calico scallops. Details of the primary processing methods are given below.

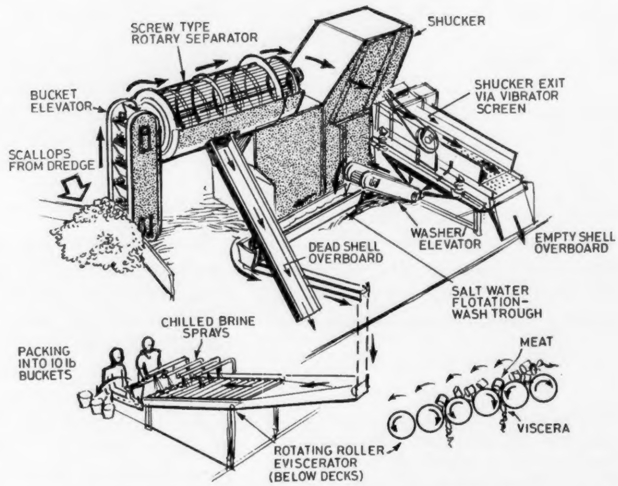


Figure 8.—Shipboard shucking machine for calico scallops. Illustration courtesy of *World Fishing*, Dorset House, Stamford St., London, England.

Sea Scallops

The procedures for shucking sea scallops aboard the vessel are essentially as follows. When the dredges are hauled back and dumped on deck, considerable trash ranging from undersized scallops, empty shells, and unmarketable species of fish up to very large boulders must be disposed of before shucking can begin. After sorting, the shell stock is dumped into the shucking boxes which line the rail of the vessel. A special knife is used to separate the shells and cut free the adductor muscle (the only part saved by U.S. fishermen). In Europe, the gonads are also saved as these are highly esteemed as a delicacy, more desirable even than the adductor muscle.

The meats are then washed in seawater and put in muslin bags which hold 35-40 pounds of meats. The filled bags are carefully iced in storage pens in the hold to keep the scallops from spoiling (Bourne, 1964; Peters, 1974).

If the scallops are to be landed whole, the trash is sorted out and the shell stock lowered into the hold and iced in the pens.

Calico and Bay Scallops

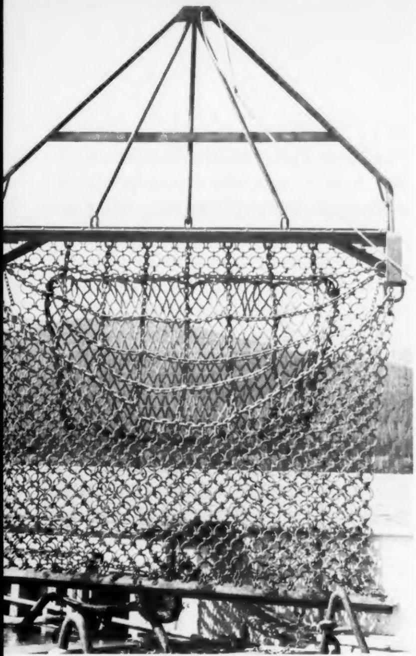
The small size of these scallops makes it almost impossible economically to shuck them by hand aboard the vessel. However, machines using a "shock-heat-shock" method have been developed, and some were installed aboard the larger vessels fishing for calico scallops off Florida's east coast. In this process, the scallops are passed through a rotary sorter to eliminate the trash. They are then fed into a tank of hot water by means of a pair of soft rollers revolving rapidly in opposite directions; the rollers grip the shells and sling them with considerable force against a steel baffle slanted at a 45° angle. The water in the tank is kept at 175°-212°F (80°-100°C), and the residence time of the scallops is only a few seconds. They are then removed by a conveyor and again passed through a pair of "slinger" rolls and thrown against another baffle. From this, they drop onto an inclined shaker screen that separates the meat and viscera from the shells. The meat plus viscera of the scallops then go to the eviscerator which consists of a large number of paired rollers. The rollers in each pair rotate first toward each other then away. The rough plastic surface tends to grip the viscera and pull it away from the meat. Then, as the eviscerator is inclined downward, the meats are propelled along to a brine tank where any remaining shell fragments sink, and the meats are removed by a conveyor to the inspection and packing tables. There are some variations on this basic method that are (or have been) in use: 1) Entrance slinger rolls only, 2) exit slinger rolls only, and 3) no slinger rolls. An early variation of this method of historical interest used a free fall of considerable height (30-40 feet) (9-12 m) onto a solid slab to provide the initial shock (Cummins, 1971).

The seagoing machines were removed from the vessels after a few years and the reasons given vary: i.e., the machine made the vessel unstable, the meats were poor in quality, the crews were unhappy, etc.

PROCESSING ASHORE

Sea Scallops

With the recent exploitation of sea scallop beds off the coasts of New Jersey and the Delmarva Peninsula, there has been a significant increase in the amounts of scallops landed in the shell and shucked ashore. Both hand and machine shucking are used. The procedures are essentially the same as those described above. On the west coast, a machine was developed and patented by the NMFS Seattle Technological Laboratory (now the Pacific Utilization Research Division, Northwest and Alaska Fisheries Center, NMFS,



An 8-foot New Bedford-type scallop dredge.

A 10-foot Georges Bank-type scallop dredge with a catch of calico scallops.

NOAA, Seattle, Wash.). This machine uses oxyacetylene flames to loosen the adductor muscle from its attachment to the shell. The shells are removed mechanically and the viscera separated from the meat by suction (Nelson, 1970).

After shucking or after landing the shucked meats, the meats are washed; large sea scallops are cut by hand into smaller "bite-size" pieces. They are then either packaged in 1-, 5-, or 10-pound (0.5-, 2.25-, or 4.5-kg) packages and frozen in a plate freezer, or they are first frozen in liquid nitrogen, liquid carbon dioxide, or liquid refrigerant-12 and then packaged. The individually quick freezing methods provide very rapid freezing and a product that is of excellent appearance and convenient to use both for the housewife and for the restaurant chef.

With the increase in landings of shell stock, there has been an increase in the problems associated with disposal of the waste products—viscera and shell. Presently, the viscera are being used as an additive to animal feeds (primarily for hogs). The shells are sometimes used as fill in land reclaiming projects, crushed and added to concrete, or spread over oyster beds as cultch.

Bay Scallops

Very often, bay scallops are shucked by a family group (i.e., a cottage industry) either in a separate building or in a wing of the family home especially laid out and equipped to meet the local and state sanitation requirements. Or, the shell stock may be sold by the fisherman to a processor who then takes care of the shucking, packaging, freezing (if necessary), and distribution.

Calico Scallops

Early in this fishery, landings were quite heavy in the Cartaret County area of North Carolina, and processing was very much a cottage industry. Trucks would drop off the day's catch of shell

stock at various homes where it would be shucked the next day by the housewives and, perhaps, children. The shucked meats would be picked up that evening when the next batch of shell stock was delivered. At present, calico scallop shell stock is processed in modern sanitary plants or aboard ships where quality control can be maintained much more easily and uniformly than in the cottage industry situation (Fig. 7) (Thomas[2]).

QUALITY PROBLEMS

Most of the problems that have been identified are for sea scallops. Regulations regarding sanitation in the shucking process aboard the vessel vary from state to state. In general, it is required that stainless steel or plastic containers, wash boxes, and sometimes shucking benches be used, so it will be possible to easily sanitize the equipment (O'Brien, 1961).

When the shuckers aboard the vessel fill their pails with meats, they dump them in the wash box where they may soak in seawater for as long as 6 hours. In summer, the temperature of the wash water may be 70°F (21°C) or even higher. When the bags of scallop meats are iced down in the hold, the meat temperature begins to drop slowly, the filled bags contain 3½-4 gallons (13-15 liters) and measure about 16-18 inches (400-450 mm) high by 6-8 inches (150-200 mm) thick; to cool this bulk in melting ice (which is about the most efficient chilling agent known) takes many hours. It could be as short as 8 hours, but it could also be as long as 36 hours. The time depends on meat temperature and thoroughness of icing. And as quality loss in iced products is directly related to time at a specific temperature, it is very important that temperatures be lowered as close to ice temperature as possible and in as short a time as possible. It has been found that the quality of sea scallop meats on landing was greatly improved by rapid chilling in refrigerated seawater (RSW) prior to bagging. In these tests, the RSW was held at 30°-32°F (−1°-0°C), and the equipment was capable of cooling 300 pounds (136 kg) of scallop meats from 70°F (21°C) to 32°F (0°C) in 1 hour. The increase in quality was equal to an increase of iced storage time of 2-9 days as compared with meats not prechilled in RSW. Ordinarily, 10-12 days is considered the maximum storage period for iced sea scallop meats (Varga and Blackwood, 1969).

At present, no vessels are equipped for freezing scallop meats on board. In some preliminary tests, it was found that even poor freezing methods gave better results than when iced scallop meats are frozen ashore. As an example, scallop meats packed in 5-pound (2.25-kg) cartons and slowly frozen aboard the vessel (approximately 24 hours to reach 5°F (−15°C)) were of superior quality during a storage period of 12 months at 0°F (−18°C) to scallop meats held on ice for 2 days in the usual cotton bags, then packaged and plate frozen ashore (Peters, et al.[3], 1959). Research done in Canada also shows that the quality of scallop meats frozen prerigor is significantly better than that of scallops frozen ashore (Dyer and Hiltz, 1974).

The frozen storage life of scallop meats conventionally iced, frozen, and stored at 0°F (−18°C) is considered to be about 12 months. However, no work has been done to determine the influence of length of iced storage on the quality of scallop meats during subsequent frozen storage.

The landing of sea scallops in the shell from the offshore banks is relatively new. The problems involved with this procedure are not yet fully known or properly evaluated. Some processors have found that some vessels are not icing the shell stock as well as they should; but, at present, there are no guidelines available to show the vessel captains the best procedures for stowage.

There is also a difference of opinion about the effect on quality of machine shucking as compared with hand shucking. A processor who uses hand shucking claims that even the very brief exposure of the meats to hot water, as experienced in machine shucking, causes significant cooking of the meats that makes them unacceptable to his customers. A proponent of machine shucking, however, says he has no problem at all in selling his sea scallop meats.

A possible problem area results from the fact that sea scallops cannot close their shells tightly and, thus, die quite rapidly when taken out of the water; and when they die, the shells tend to gape open. The gaping exposes the interior of the scallop to the melt-water from the ice used to cool the product. The melt-water will contain various amounts of mud washed from the shells as it flows over them. It is very difficult (if not impossible) to get the shell stock clean before icing in the hold. To do a really good job would require equipment specially designed and constructed for shipboard installation. A brief rinsing with the deck hose will not do the job.

It is very doubtful that bacteria of public health significance are present in the offshore waters, but there is no guarantee that the scallop meats do not pick these up during subsequent handling. Only strict observance of the fundamental rules of sanitation will insure a completely wholesome product.

Paralytic shellfish poisoning (PSP) is not a problem with scallops. Occasionally, the livers and mantles have measurable toxicity, but PSP has never been found in the adductor muscle and only in very minor amounts in the roe (Bourne, 1965).

AQUACULTURE

A possible solution to the problems of steadily declining catch of sea scallops and the great fluctuations in landings of bay and calico scallops might be found in the application of aquaculture to these species.

Sea Scallops

Surprisingly little work has been reported on the growth of sea scallop lar-

[2]Frank B. Thomas, North Carolina State University, P.O. Box 5592, Raleigh, NC 27607. Pers. commun.

[3]Peters, J. A., D. T. McLane, D. M. Lukshin, and J. W. Slavin. 1959. Tests on the freezing and storage of scallop meats. U.S. Fish Wildl. Serv., Technological Laboratory, East Boston, Mass. Unpubl. manuscr.

vae under laboratory conditions. Early reports indicated little success in raising sea scallop larvae (Posgay, 1953). One researcher, however, recently succeeded in raising sea scallops to maturity in the laboratory and considers this species to be a prime subject for commercial aquaculture (Culliney, 1974). On the other hand, other workers consider that there are more unfavorable characteristics than favorable. Among these are the fact that sea scallops are slow growing requiring 3-4 years to reach marketable size as compared with 1 year for the bay scallop. Also, growth rate cannot be increased by increasing the water temperature. Sea scallop growth is greatest at 50°F (10°C) and declines rapidly above this temperature, ceases entirely at about 68°F (20°C), and the animals die at about 73°F (23°C) (Gates and Mathiessen, 1971; Posgay, 1953).

Bay Scallops

Several scientists have successfully grown bay scallops under controlled conditions, and one of them reports that they will reach marketable size in 5 to 7 months; however, the procedure is, at present, very labor intensive (Castagna, 1975).

Calico Scallops

Very little has been published on raising calico scallops under controlled conditions. Spawning can be induced fairly easily, but this author has found no reports of successful rearing to marketable size.

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MFR PAPER 1353

Blue Crab Larval Culture: Methods and Management

MARK R. MILLIKIN

ABSTRACT–Larval culture methods of the blue crab, Callinectes sapidus, *and its associated food organisms are described in order to provide a guide for rearing larvae for experimental and commercial purposes. Environmental parameters and advantages of controlled rearing of blue crab larvae are discussed. Information on optimal water quality parameters appears to be further developed than that for nutritional requirements of the individual larval stages. Metamorphosis and survival of various blue crab larval stages fed several live food organisms are described with additional discussion of the culture of each food organism.*

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INTRODUCTION

The reasons for annual fluctuations in commercial blue crab landings from the mid Atlantic, south Atlantic, and Gulf Coast areas include: 1) Bad year classes due to low hatchings from the previous year, 2) natural catastrophes, 3) overharvest in previous years, 4) lack of eelgrass or other protective vegetation to provide refuge for soft crabs and smaller juveniles, and 5) pollution of estuarine areas where juveniles feed.

Closed system larval rearing offers an alternative with increased control over environmental parameters. Some advantages of closed system rearing are: 1) No natural catastrophes, 2) no pesticides and other harmful chemicals, 3) no predation, and 4) no cannibalism when individuals are reared separately. The importance of the blue crab to the seafood industry warrants serious consideration of the methods described in this review as a tool of management to supplement fluctuating natural populations. Any experimental work in blue crab larval culture would also benefit from the following discussion.

METHODS

Survival in Natural VS Artificial Systems

The size of a normal egg mass from an ovigerous female has been estimated at $1.75 \times 10^6 - 2 \times 10^6$ eggs by Churchill (1921) and 2×10^6 eggs by Davis (1965) and Warner (1976). Survival to the mature adult under natural conditions has been estimated to be one out of every 2 million eggs produced (Warner, 1976). Under laboratory rearing conditions, Sulkin et al. (1976) reported 22.5-30 percent survival to the megalops stage. Costlow[1] has observed survival, under carefully controlled conditions, to the first crab stage ranging from 0 to 40 percent. The rate of survival of the blue crab increases dramatically under laboratory conditions after reaching the first crab stage. Unpublished results from our laboratory with crabs raised from the first stage to juveniles (ranging from 3 to 7 cm in width) indicated 80 percent survival in a group of 400 individuals maintained in compartmented plastic boxes suspended in glass aquaria containing artificial seawater. Since environmental variables such as temperature, salinity, and dissolved oxygen have been defined for the successful controlled culture of blue crab larvae, a better understanding of their nutritional requirements and feeding behavior would appear to be a major concern in any effort to increase larval survival.

Mating and Spawning

Female blue crabs mate only once in

[1]John D. Costlow, Duke University Marine Laboratory, Pivers Island, Beaufort, NC 28516. Pers. commun.

their lifetime. Mating occurs after their terminal molt in the soft crab stage. Enough sperm is received and stored in the female's spermathecae for two and possibly three spawning periods (Hard, 1942).

Induced mating requires a knowledge of the molt cycle of the male and female. In the mating process, the male should have molted recently while separated from the female, so that the next molt to occur will be that of the female. Otherwise, in the presence of the female the soft crab stage male would be cannibalized. However, the female is protected by the male before, during, and after her terminal molt. Van Engel (1958) describes the coloration of the abdomen of the immature female crab as grayish-white and that of the adult female as blue-green. In the last few days before the final molt of the female, the dark green of the inner, soft, mature abdomen shows through the translucent whiteness of the hard, outer, immature abdomen. This change, in addition to the red line stage on the border of the swimming paddle of the pre-molt female, should provide ample warning that the terminal molt is approaching. Abdominal appearance of the male can also be used to determine its status as a mature or immature individual. According to Van Engel (1958), the abdomen of an immature male is tightly sealed on the ventral surface of the shell, while on a mating male the abdomen hangs free or is held in place by a pair of snap fastener-like tubercles.

Induced mating and spawning under laboratory conditions should include a holding tank with a muddy or gravel bottom to simulate the natural environment. Blue crabs and some other crustaceans such as the freshwater prawn, *Macrobrachium rosenbergii*, appear to abort egg masses frequently on smooth, unnatural bottoms such as glass, fiberglass, and Plexiglass[2]. A minimum of 2-3 months is required after mating before ovulation occurs. In natural waters, such as the Chesapeake Bay, ovarian development may come to a halt during winter months as females cease feeding activity below 10°C (Churchill, 1921). Dredged, overwintering females may be induced to renew ovarian development and subsequent spawning after an acclimation period of increasing water temperatures under laboratory conditions.

Egg Development In Vitro

An alternative to natural egg development and spawning has been provided by Costlow and Bookhout (1960). This method provides several essentials for viable egg development: 1) Adequate aeration, 2) control of fungi and protozoans in the egg mass, and 3) prevention of aborted egg masses which females accomplish through tearing with their walking legs. Eggs are cut from swimmerets previously placed in 30‰ seawater with fine scissors and then further dissociated with glass needles into groups of 100-1,000. The eggs are then placed in plastic compartmented boxes (9 cm^2) containing 20 ml of 30‰ freshly filtered seawater treated with penicillin (200,000 units/l). The boxes are placed on an Eberbach variable speed shaker (110-120 rpm) and maintained at 22-25°C. Hatching of viable eggs was determined at or near 100 percent in compartments containing 100-1,000 eggs. According to Pyle and Cronin (1950), hatching occurs approximately 2 weeks after egg extrusion onto the swimmerets. Churchill (1921) found hatching time, after egg extrusion, to vary slightly with different temperature regimes. At a temperature of 26.1°C (79°F) hatching of eggs required 14-17 days; at 29.4°C (85°F), hatching required 12-15 days. Segregation of limited size egg masses reduced the spread of the fungal egg parasite, *Lagenidium callinectes*. Additionally, by controlling salinity, this method avoids premature larval hatching due to low salinities, which can occur in natural waters (Van Engel, 1958).

The Egg Mass: Age and Disease

According to Bland and Amerson (1974), the color of the egg mass can be used in determining approximate age of the eggs, which can provide a reasonable indication as to how many days are left before a holding apparatus for first stage zoeae should be made available. A yellow to orange color is characteristic of eggs that have been on the swimmerets 1-7 days. Brown to black sponge color indicates 8-15 days have passed since egg extrusion onto the swimmerets.

Two particular diseases of the blue crab egg masses more common than others are: 1) Fungal disease caused by *L. callinectes* and 2) parasitic infestations by the nemertean, *Carcinonemertes carcinophila*. The fungal disease primarily invades immature embryonic stages. Heavily infected eggs can be recognized by their smaller size and greater opacity (Sindermann, 1974). The fungus develops in salinities from 5 to 30‰, spreading rapidly onto the peripheral eggs while avoiding the center of the egg mass. Infected eggs do not hatch and zoeae hatched from eggs previously uninfected may still become infected if left in medium containing fungus spores. Female crabs with infected egg masses should be removed from brood tanks immediately. Immature *C. carcinophila*, living in the gill tissues of the gravid female, migrate to the egg mass after extrusion onto the swimmerets. The worms become sexually mature only in the egg mass. After mating, the female *C. carcinophila* withdraws from its mucus tube, leaving large numbers of eggs within the blue crab egg mass. Development and hatching of nemertean eggs occur within 36 hours. Some migrate back to the gill chambers of the adult female crab, while others swim freely from the host to infest other crabs. However, the damage caused from the nemertean parasite is not as extensive as that caused from the fungal disease.

Characteristics and Optimal Water Quality Parameters for Zoeal Survival and Development

Blue crabs normally go through seven zoeal stages but have survived to the megalops after only six zoeal stages (Sulkin et al., 1976) and even following

[2]Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

a supernumerary eighth zoeal stage (Costlow and Bookhout, 1959). Each of the seven normal zoeal stages has morphological changes described in detail by Costlow and Bookhout (1959). Zoeae are heliotropic and free-swimming but are classified as planktonic due to a lack of control of their position in tidal and strong current areas. In natural environments, eggs appear to successfully hatch in salinities of 23-30‰. Costlow and Bookhout (1959) and Sulkin and Epifanio (1975) reported that the optimal temperature for zoeal development is 25°C. Optimal salinity for zoeal development ranges from 26‰ (Costlow and Bookhout, 1959) to 30‰ (Sulkin et al., 1976). Additionally, Sulkin et al. (1976) found synthetic seawater to compare favorably to natural seawater in terms of zoeal survival as 50 larvae (5 sets of 10) in natural water achieved 22.5 percent survival through the megalops stage, whereas a comparable number of larvae in synthetic seawater attained 30.0 percent survival through the megalops stage. Larvae rarely completed their first molt to second stage zoeae in salinities lower than 20‰ or temperatures below 20°C (Costlow and Bookhout, 1959). Mortality of blue crab larvae was highest during the first two zoeal stages (Costlow and Bookhout, 1959). A comparison of environmental parameters used by different investigators is summarized in Table 1.

Total time for zoeal development ranged from 31 to 49 days for the seven stages (Costlow and Bookhout, 1959) compared with an average duration of 35.7 days when only six zoeal stages occurred (Sulkin et al., 1976).

Blue Crab Larval Feeding

Little if any qualitative or quantitative research has been conducted on nutritional requirements of the zoeal stages of the blue crab. With regard to natural foods, several plant and animal organisms have been evaluated for their ability to support survival and growth of larvae to the megalops stage.

According to Costlow and Bookhout (1959), unicellular algae when fed as a sole food source did not provide enough nutrition for successful molting from the first to second zoeal stage, although ingestion by the zoeae was observed for up to 10-13 days, apparently resulting in a somewhat prolonged survival time. Rust and Carlson (1960) observed no apparent utilization of the following phytoplankton by blue crab zoeae: *Gymnodinium*, *Amphidinium*, *Chlamydomonas*, *Platymonas*, *Isochrysis*, *Monochrysis*, *Prorocentrum*, *Nitzschia*, *Carteria*, *Chlorella*, or *Dunaliella*. Possibly one reason that algal species have failed to promote growth of zoeae is that algal diets are totally devoid of animal sterols, which appear essential in the diet of the blue crab. Whitney (1970) found that the blue crab is incapable of de novo synthesis of cholesterol from either acetate-^{14}C or mevalonate-^{14}C. Based on her studies, Whitney theorized that rapid molting and tissue growth in the larval stages require large amounts of sterols for new subcellular membrane formation.

Sulkin (1975) has reared zoeae from the first stage to the megalops with a survival rate of 17 percent on a diet of gastrulae and trochophores from the polychaete, *Hydroides dianthus*. In the same study, rotifer-fed zoeae did not reach the megalops stage, although some survival through the eighth zoeal stage was observed. Mortalities in zoeal stages III, IV, and VII were significantly lower in polychaete-fed crab larvae than in those fed the rotifer diet. Brine shrimp nauplii, *Artemia salina*, alone did not sustain growth from the first to second zoeal stages, and mortality occurred unless either rotifer or sea urchin egg supplements were provided (Sulkin, 1975). Costlow (pers. commun., footnote 1) has also recommended using sea urchin eggs (*Arbacea* sp.) along with freshly hatched *Artemia* nauplii (less than or equal to 12 hours old) for the feeding of zoeal stages I and II. Freshly hatched *Artemia* nauplii may be used as the sole food organism for zoeal stages III-VII. The size of feed organisms appears to determine the blue crab zoea's ability to capture prey (Sulkin and Epifanio, 1975). This would explain the apparent lack of survival of first and second stage blue crab zoeae when brine shrimp nauplii are offered as the sole food.

Table 2 lists the sizes of several live food organisms fed to blue crab zoeae by Sulkin and Epifanio (1975). These investigators concluded that food organisms of 110 μm or less are optimal for the first and second zoeal stages.

Sulkin and Epifanio (1975) made a comparison between groups of stage I and II zoeae fed either sea urchin gastrulae or a rotifer diet. After 14 days, survival in the sea urchin gastrulae-fed group equalled only 5 percent as compared with 50 percent among the rotifer-fed animals.

Sulkin (1975) has suggested that the high degree of success in rearing zoeae through the later stages with brine shrimp nauplii may be due to the high lipid content of the nauplii, which in fact may be required as larval metamorphosis approaches. Sea urchin larvae (derived from isolecithal eggs) are inferior to polychaete and brine shrimp larvae (derived from telolecithal and centrolecithal eggs) in supporting larval metamorphosis of the blue crab to the megalops stage. This may indicate that the type of embryological development determines the nutritional value of the particular food organism as a zoeal food source for the later stage zoeae (Sulkin, 1975). Total lipid per unit dry weight as determined by Sulkin (1975) for several food organisms is as follows: mixed rotifers—8 percent,

Table 1.—Environmental parameters used for zoeal culture.

Item	Costlow and Bookhout (1959)	Sulkin and Epifanio (1975)
Temperature	25°C	25°C
Salinity	26‰	30‰
Photoperiod	12 light/12 dark	14 light/10 dark

Table 2.—Maximum sizes of several live food organisms offered to blue crab zoeae[1].

Organism	Size (μm)
Rotifer (*Brachionus plicatilis*)	45-80
Sea urchin egg (*Arbacea punctulata*)	72-75
Sea urchin egg (*Lytechinus variegatus*)	110
Recently hatched nauplius (*Artemia salina*)	250

[1]From Sulkin and Epifanio (1975).

large rotifers—9 percent, the polychaete, *H. dianthus*—20 percent, and brine shrimp nauplii—30 percent.

Careful selection of potential food organisms, based not only on their ability to promote maximal survival and growth, but also on their freedom from organic and inorganic contaminants as well as biological vectors, is an important consideration for the larval culturist. Bookhout and Costlow (1970) demonstrated the importance of the geographic region from which brine shrimp originate in feeding studies with newly hatched blue crab zoeae fed either San Francisco Bay or Great Salt Lake brine shrimp. Upon analysis for DDT in brine shrimp from the Great Salt Lake, a total of 7,050 parts per billion (ppb) were detected, whereas San Francisco Bay brine shrimp contained approximately 2,300 ppb. Although the length of time required for development to the megalops stage was similar for both brine shrimp-fed groups (about 46 days), there were some indications (Table 3) that the higher pesticide levels detected in Great Salt Lake brine shrimp may have produced greater mortality. Despite the current lack of technical knowledge on the specific nutritional requirements of the blue crab zoeae, with present rearing methods and associated feeding techniques, the larval culturist can be reasonably assured of achieving significantly better survival through the first seven zoeal stages than that known to occur in nature.

The final zoeal stage of the blue crab metamorphoses into the megalops, which precedes the first crab stage or instar of the juvenile period of development. The megalops exhibits benthic as well as planktonic behavior, allowing for better utilization of food throughout the water column than the strictly planktonic zoeal stages. Churchill (1921) reported average sizes of the megalops and the first crab as 0.102 cm and 0.254 cm, respectively. External anatomy of the megalops stage is described in detail by Costlow and Bookhout (1959).

Costlow (1967) fed newly hatched *Artemia* nauplii to blue crab megalops and monitored the effects of various salinity-temperature combinations on survival and rate of development to the first crab stage. The optimal salinity-temperature combination was determined to be 25°C and 30‰ as 100 percent survival was achieved with an average of 8.4 days (6-12 days) required for metamorphosis to the first crab. Sulkin (1975) found that nearly all megalops successfully metamorphosed to the first crab stage when fed *Artemia* nauplii and occasional pieces of fish. However, no megalops reached the first crab stage when fed exclusively on the polychaete, *H. dianthus*. Due to the increased mobility and larger claw size, the megalops of the blue crab is able to prey on *Artemia* nauplii of a larger size range than may be eaten by the zoeae. However, adult *Artemia* should not be fed until the blue crab reaches the first crab stage (Costlow, pers comm., footnote 1).

Table 3.—Survival of blue crab larvae fed brine shrimp obtained from two different geographic regions[1].

Region	Percent molted into normal megalops	Percent molted into first crab stage
Zoeae fed *Artemia salina* from San Francisco, Calif.	50	34
Zoeae fed *Artemia salina* from Great Salt Lake, Utah	31	24

[1]From Bookhout and Costlow (1970).

Holding Tanks for Mass Culture of Blue Crab Larvae

A combination larval hatching-collection chamber designed by Smith and Hopkins (1977) for separating newly hatched freshwater prawn, *M. rosenbergii*, from egg-bearing females appears suitable for use with the blue crab (Fig. 1). This system utilizes air lift pumps that discharge 7.6 liters/minute of water into the hatching chamber, providing a current which carries larvae through a nylon screen (0.6 cm mesh size) into the collection chamber. Light above the collection chamber causes positive phototactic response of crustacean larvae to concentrate most individuals near the surface for easy retrieval. Because outstretched stage I blue crab zoeae range from 300 to 400 μm and sphere-shaped zoeae range from 200 to 300 μm, a screen with a 100μm mesh size is recommended for separation of the larval collection chamber from the biological filter section to prohibit flow of larvae past the larval collection chamber. As a result of using a smaller screen mesh size than that recommended for freshwater prawn, differences in head loss may be reduced through decreased flow rate or increase in surface area of the screen.

Serfling et al. (1974) designed a recirculating culture system (Figs. 2, 3) for larvae of the American lobster, *Homarus americanus*, which is a modified version of an earlier system developed by Hughes et al. (1974). It would appear that Serfling's sytstem offers a practical holding system approach for the mass rearing of blue crab larvae even though the first two zoeal stages would have to be separated from the last five zoeal stages due to different food organisms being offered (i.e., rotifers for zoea I and II and brine shrimp nauplii for zoea III to VII). Either a duplicate system or compartmented boxes would be required for the first two zoeal stages. The system described by Serfling et al. (1974) has a 10 liter/minute flow rate for larval dispersal and provides primary filtration through a graded sand (No. 12 silica) and crushed oyster shell filter bed. Secondary filtration includes a charcoal and fiber filter used to remove chemical contamination and residual particulate wastes. Serfling et al. (1974) also discusses the use of heating elements as well as occasional ultraviolet sterilization of the water, together with antibiotics.

Culture of Feed Organisms for Blue Crab Larvae

Environmental parameters, algal species, and feeding rates, which provide optimal survival and development for the culture of the rotifer, *Brachionus plicatilis*, and the brine shrimp, *A. salina*, will be described in order to provide ample food for blue crab larvae in a larval culture operation.

The rotifer, *B. plicatilis*, is described as a mixohaline species because of its

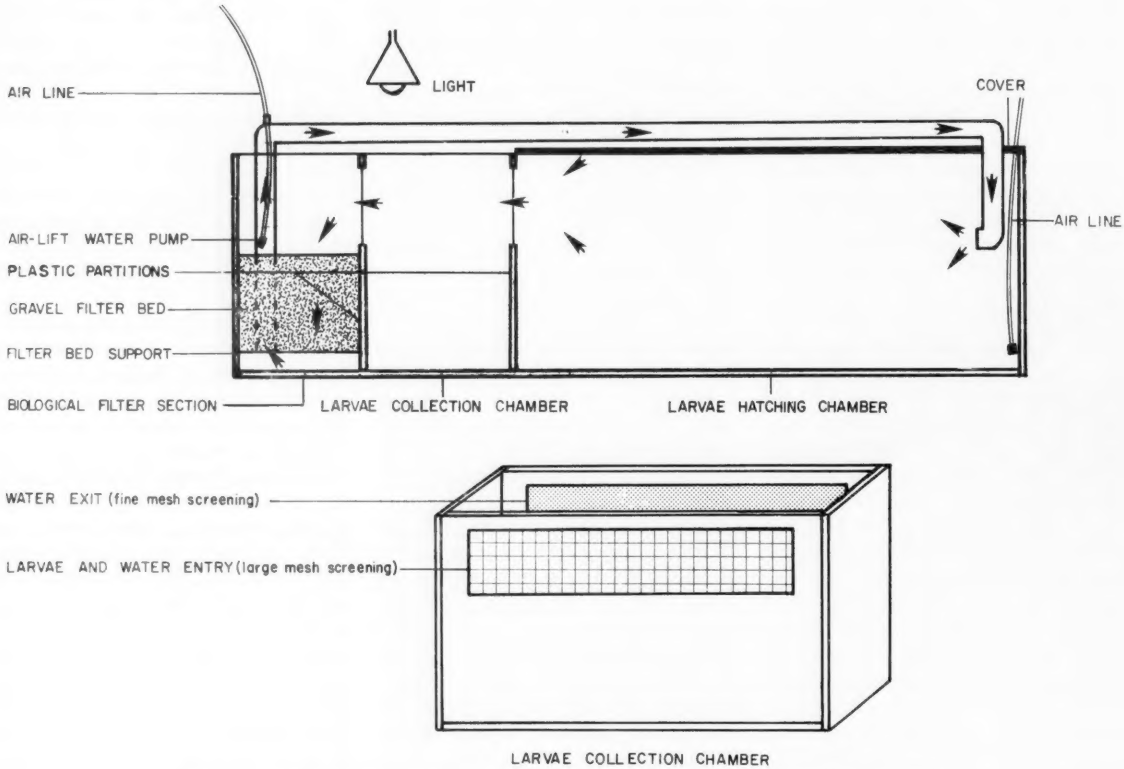

Figure 1.—Longitudinal and frontal view of hatching-collection chamber (Smith and Hopkins, 1977).

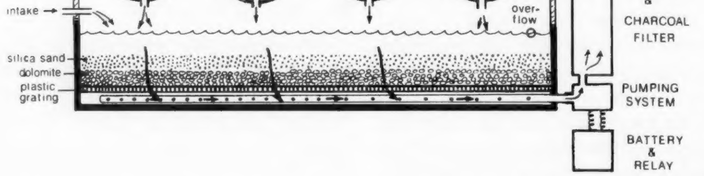

Figure 2.—Front, cross-sectional view of the recirculating culture system, showing the Hughes Culture Tank and the Circulator design and the primary and secondary filtration systems. Illustration is from Serfling et al. (1974), courtesy of Elsevier Scientific Publishing Company, Amsterdam, The Netherlands.

tolerance of a wide salinity range (0.5-40‰) without any apparent adverse effects (Theilacker and McMaster, 1971). This species is easily obtained and cultured as a result of its wide tolerance to variable environmental parameters. To maintain an optimal environment for both rotifer culture and its algal food source, a water salinity of 25‰ and a temperature of 21°-25°C were established by Theilacker and McMaster (1971). These conditions were based on observations that the reproductive rate of *B. plicatilis* was similar in either 25 or 30‰ seawater and the fact that growth of the algal food source, *Dunaliella* sp., appeared optimal at a salinity of 25‰. Based on experimentation with four algal genera, *Dunaliella*, *Nannochloris*, *Exuviella*, and *Monochrysis*, Theilacker and McMaster (1971) concluded that the

unicellular flagellate, *Dunaliella* sp., was the most practical choice. This species did not require vitamins or soil extract in the culture medium. For culture of *Dunaliella*, ultraviolet-treated 24‰ seawater was filtered through two Cuno Aqua-pure filters (pore size=5 μm), a large capacity millipore cartridge pre-filter and filter (pore size=0.45 μm), and reirradiated with ultraviolet light. Sixteen liters of medium maintained at a temperature of $24° \pm 1°C$ in 20-liter carboys were bubbled with 5 percent carbon dioxide and agitated with a magnetic stirrer under constant illumination at a light intensity of between 500 and 700 footcandles. Cell numbers were found to increase from 3.4×10^3 to 3×10^5 cells/ml in 9 days. At peak growth, 25 percent of the algal culture is removed daily and replaced with fresh media for 10 additional days. For mass rotifer production, fiberglass tanks were filled to a depth of 13 cm (464 liter volume) and inoculated with 32 liters of *Dunaliella* culture to yield a final concentration 2×10^5 cells/ml. When *Dunaliella* concentrations reached 1×10^6 cells/ml (2-4 days), the fiberglass tanks were charged with approximately 2×10^4 rotifers. The tanks were then aerated under constant illumination at an intensity of 140-170 footcandles. This procedure supported a production of 2.5×10^6 rotifers/day within a 4 or 5 day period. The size of *B. plicatilis* ranged from 99 to 281 μm. Average rotifer weight equalled 0.16 μg with an energy content of an individual animal determined to be 8×10^{-4} calories. An average caloric content was estimated at $5{,}335 \pm 139$ cal/g of ash-free dry weight. Rotifer concentrations as high as 200/ml did not inhibit reproduction. Separation of rotifers from the algal materials was accomplished with the aid of a submersible pump and plastic tube covered at one end with 64μm mesh netting (Theilacker and McMaster, 1971).

Techniques for producing newly hatched brine shrimp nauplii have been thoroughly described by Sorgeloos and Persoone (1975). Hatching of cysts in seawater was found to require a salinity between 5 and 70‰. However, Boulton and Huggins (1977) compared hatching rates in salinities of approximately 0, 17.5, 35, 52.5, and 70‰ seawater after hydration for 6 hours as well as after subsequent 3-hour intervals up to 30 hours. No free swimming nauplii were observed in 50 percent diluted seawater after 30 hours of hydration. Highest percentage hatching occurred in full-strength seawater after 27 hours (63 ± 11 percent) and 30 hours (69 ± 9 percent). Hatching rate in higher salinities was greater with each additional 3-hour interval from initial hydration but remained lower than that achieved in full-strength seawater. For "Californian cysts," illumination for 10 minutes at an intensity of approximately 185 footcandles (2,000 lux) in a medium containing at least 3 ppm dissolved oxygen is sufficient for successful hatching (Sorgeloos and Persoone, 1975). These same authors have reported an optimal temperature to equal approximatley 30°C. Foaming (protein bubble formation), which is caused by decomposed byproducts of dead *Artemia*, can be minimized by using a few drops of nontoxic silicone antifoamer. A cylindrical separator box constructed by Sorgeloos and Persoone (1975) capitalizes on the positive phototactic behavior of newly hatched nauplii and is an improvement over rectangular bottom containers used in the past. This separator avoids accumulation of cysts and newly hatched nauplii in corners, which causes low hatching and poor survival rates.

Culture of brine shrimp beyond the newly hatched stage is recommended in order to feed the megalops stage and early instars of the juvenile period. The phytoflagellate, *Dunaliella viridis*, is a satisfactory feed organism for newly hatched nauplii. Funnel-shaped bottoms for algal culture vessels (Fig. 4, 5) eliminate sedimentation and permit circulation of nutrients (Persoone and Sorgeloos, 1975). Some investigators have used a supplemental source of CO_2 for algal culture, whereas others,

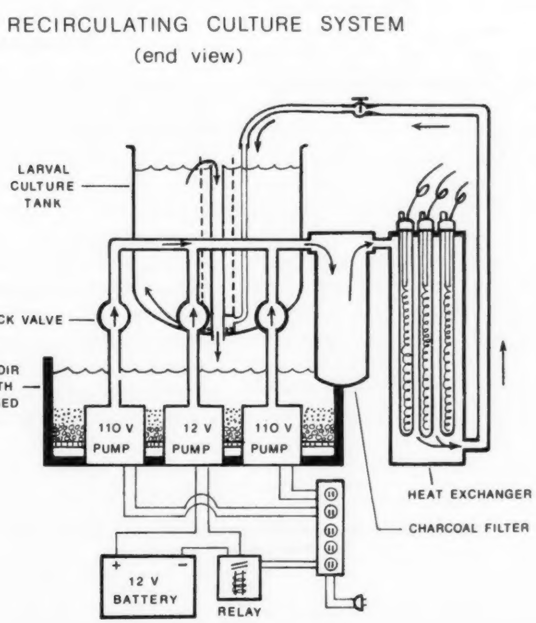

Figure 3.—End, cross-sectional view of the recirculating culture system, showing the secondary filtration and back-up power systems. Illustration is from Serfling et al. (1974), courtesy of Elsevier Scientific Publishing Company, Amsterdam, The Netherlands.

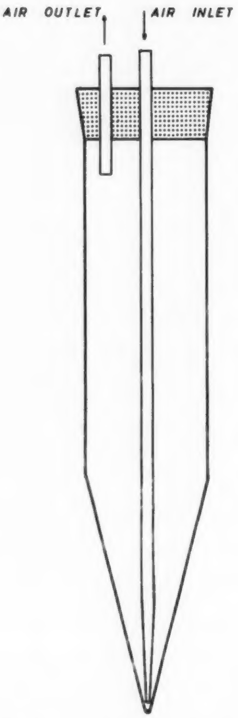

Figure 4.—Algal culturing tube, 100 ml (Persoone and Sorgeloos, 1975).

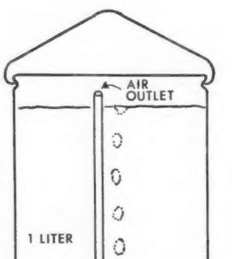

Figure 5.—Glass serum bottle used for culturing algae. (Persoone and Sorgeloos, 1975).

such as Persoone and Sorgeloos (1975), insist that in high density cultures, optical density of the culture is more limiting than insufficient amounts of CO_2. The use of axenic cultures for algal production is not generally encouraged due to: 1) Low amount of bacteria present during the exponential growth phase of the algal colony, and 2) the high expense and cumbersome work involved in keeping a bacteria-free culture. Persoone and Sorgeloos (1975) suggested the following stock solution for culture of *Dunaliella* sp.:

$FeSO_4 \cdot 7H_2O$	0.278	g
$NaH_2PO_4 \cdot 2H_2O$	3.0	g
$NaNO_3$	30.0	g
$MnCl_2 \cdot 4H_2O$	0.47	g
Glycocol	50.0	g
Distilled water	1	liter

In high density culture experiments with brine shrimp nauplii, Sorgeloos (1973) achieved concentrations of between 1 and 3 nauplii/ml at a temperature of 28°C as follows: 1) 2,000 individuals in 1-liter containers (2 nauplii/ml); 2) 25,000 individuals in 10-liter containers (2.5 nauplii/ml); and 3) 50,000 individuals in 30-liter containers (1.6 nauplii/ml). Each nauplius required 50,000 *Dunaliella* cells twice daily during the first 4 days of culture and 100,000 *Dunaliella* cells during days 5 through 8. One minute of air bubbling every half hour by an air pump, which is switched on by a timing clock, provides adequate aeration and recirculation of *Dunaliella* cells. Additionally, Sorgeloos (1973) recommends growing *Artemia* larvae in complete darkness to provide a faster growth rate. Sick (1976) monitored carbohydrate, lipid, and protein values for several phytoplankton species fed to brine shrimp larvae and found better growth in larvae fed high protein-lipid species, such as *D. viridis* and *Chlamydomonas sphagnicolo*, as opposed to high carbohydrate species, such as *Nitzschia closterium*. Paffenhöfer (1967) determined the average content of newly hatched *Artemia* nauplii to be 5,953 cal/g ash-free dry weight.

Use of dry powder forms of a feed organism as a substitute for live cultures minimizes the number of living links necessary to culture the desired species. Person - LeRuyet (1976) has developed a technique for intensive rearing of brine shrimp larvae using the blue-green alga, *Spirulina maxima*, in dry powder form. On a weekly basis, productions of 75 g of dry matter of brine shrimp from a 450-liter tank were attained. Table 4 summarizes optimal concentrations of larvae and the amount of dry powder required. The average size of an individual larva as well as optimal concentration compares favorably with previous results attained by Sorgeloos (1973) using live food for *Artemia* larvae.

SUMMARY

Extensive research by many investigators has provided useful information on the culture of feed organisms for use in blue crab larval culture. Each food organism has its own environmental parameters for optimal survival and growth. Often, this dictates a compromise of environmental parameters between any two adjacent organisms in the food chain, e.g., *Dunaliella* and *Artemia* or *Artemia* and *Callinectes*. As more knowledge of nutritional requirements is gained, formulated feeds could become practical for economic

Table 4.—Growth of larval *Artemia salina* as influenced by algal food concentration and larval density[1].

Days	No. of larvae	Amt. (mg) of powder[2] offered	Brine shrimp larva size $\bar{X}$ (mm)	Adjusted larval concentration/ml
0-2	10,000	600	1 (after 2 days)	13-14
3-4	10,000	1,800	2 (after 4 days)	5
5-6	10,000	4,300	3.75 (after 6 days)	2

[1]From Person - LeRuyet (1976).
[2]Blue-green alga, *Spirulina maxima*, in dry powder form.

purposes as well as easing the amount of work associated in culturing food organisms required for blue crab larvae.

Presently, it appears that brine shrimp nauplii, in combination with sea urchin eggs or rotifers, may be fed successfully to the first two zoeal stages, while brine shrimp nauplii appear to be the best available food organism for the subsequent zoeal stages (III-VII). The megalops stage requires brine shrimp nauplii in order to metamorphose into the first crab stage under laboratory conditions.

Despite extensive work by several investigators, survival of blue crab larvae under laboratory conditions remains below that attainable with other crabs (i.e., the mud crab, *Rhithropanopeus harrisi*, and the stone crab, *Menippe mercenaria*). Although highly variable, Costlow (pers. commun., footnote 1) has indicated a maximum survival rate to the first crab stage of approximately 40 percent.

Studies monitoring the nutritional requirements of juvenile crabs have been highly successful when using hatchery-raised individuals as opposed to individuals captured from natural waters (Biddle, pers. commun., footnote 3). Juveniles obtained from natural waters frequently succumbed to disease after transfer to laboratory holding systems, whereas hatchery-raised crabs did not exhibit similar problems.

ACKNOWLEDGMENTS

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MFR PAPER 1354

The 1976 Catch of Bowhead Whales, *Balaena mysticetus*, by Alaskan Eskimos

WILLMAN M. MARQUETTE

INTRODUCTION

The bowhead whale, *Balaena mysticetus*, is found in Arctic and northern subarctic waters. Its numbers were greatly reduced over a period of about 300 years, initially in the European Arctic and then in the eastern Canadian Arctic as well as in the Sea of Okhotsk. Commercial whaling for bowheads began in the Chukchi and later Beaufort Seas during the mid-1800's; the last reported voyage occurred in 1916 (Bower and Aller, 1917) when the steamer *Herman* and the auxiliary whaling schooner *Belvedere* sailed north in the spring from San Francisco, Calif., and Seattle, Wash., respectively, returning that autumn with some whale products. Some of the Arctic Alaska trading companies continued to deal in whalebone for a few more years into the early 1920's. These animals have been completely protected from commercial whaling by the Convention for the Regulation of Whaling of 1931; the International Convention for the Regulation of Whaling since 1946; and, subsequently, by the U.S. Marine Mammal Protection Act of 1972 and the U.S. Endangered Species Act of 1973. However, aboriginal whaling is still allowed.

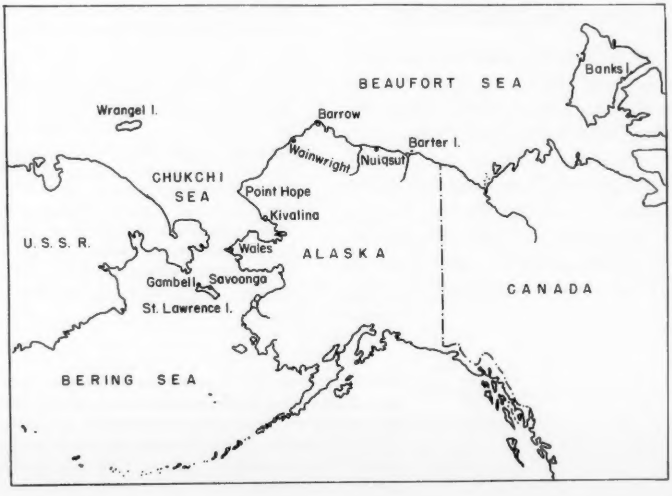
The bowhead whale, also known as the Greenland right whale, Arctic right whale, and the great polar whale, is a large cetacean that grows to about 18.3 m (60 feet) in length. It is black or dark gray, often marked with white on the chin and underside. Instead of teeth its mouth contains about 600 baleen plates that strain from the water the zooplankton upon which it feeds. It has a very large head, approximately one-third the length of the body; because the skull is long and narrow and because in profile the upper jaw is almost semicircular and bow-shaped, early Yankee whalers in the western Arctic called it the bowhead whale.

The bowhead whale of the western Arctic inhabits waters extending from the Bering Sea in the winter to the northern Chukchi and Beaufort Seas in the summer. The animal is found along the loose edges of the ice pack and moves northward as the ice recedes in the spring and southward as it extends in the winter. The bowhead's spring migration route passes between St. Lawrence Island and the Chukchi Peninsula, through Bering Strait and along the northwest Alaskan coast, then through the Beaufort Sea to the Banks Island region and the MacKenzie River delta. In autumn, the whales migrate westward along the north coast of Alaska to the vicinity of Wrangel Island, where they turn southward along the coast of the U.S.S.R. to the northern Bering Sea.

During its spring migration, the bowhead is usually seen singly or in pairs, often in the company of belukhas or white whales, *Delphinapterus leucas*. During its autumn migration these animals are frequently seen in groups that may contain up to 50 members.

Historically, coastal Eskimos established their villages at locations where points of land provided access to the bowheads during their migrations. The hunters of several villages participated in the spring hunt, but because the

Figure 1.—Map of bowhead whale study area.



whales cross the Chukchi Sea to the coast of the U.S.S.R. in autumn, residents of only a few villages along the north coast of Alaska hunted them at that time. Residents of Gambell and Savoonga on St. Lawrence Island and the mainland villages of Wales, Kivalina, Point Hope, Wainwright, and Barrow engaged in spring whaling. Ice conditions east of Barrow did not permit spring whaling by residents of Nuiqsut or Kaktovik (on Barter Island), but these people and the Barrow whalers participated in the autumn hunt. The locations of Alaskan whaling are shown in Figure 1.

The hunting of bowhead whales for subsistence has been a vital part of Eskimo life for at least 3,500 years (Oswalt, 1967). Present day whaling is conducted by the Eskimos of St. Lawrence Island, the Siberian coast, and the Arctic Alaskan coast using a combination of traditional and modern equipment and techniques.

Because of its isolation in the Arctic environment, the bowhead whale has been subject to little biological research. An expanding Eskimo harvest of this species and the impending development of the oil resources of the Alaskan continental shelf have an unknown effect on the survival of the bowhead whale population. Reliable information on the natural history, numbers of animals, and migratory patterns is incomplete for proper evaluation of the effects of the Eskimo harvest and oil exploration.

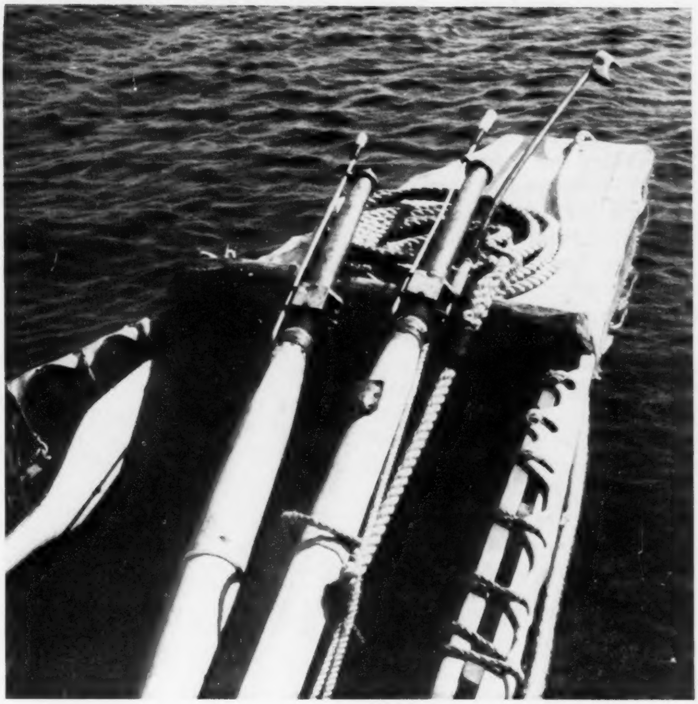


Figure 2.—Two darting guns in position in the bow of the skin boat are ready for instant use. One gun has a harpoon attached that is secured to a float by a line about 61 m (200 feet) in length.

RESEARCH OBJECTIVES AND METHODS

The current research objectives of the National Marine Fisheries Service (NMFS) are to determine the status of the bowhead whale, the impact of the Eskimo fishery on population size, and the effects of oil exploration and exploitation upon this species.

Observers monitor the harvest during the spring whaling season at Point Hope and Barrow from about 20 April to 7 June and during the autumn whaling season at Barrow from about 15 September to 30 October. They visit the whaling camps as often as possible and gather information on the number of bowheads sighted, killed and recovered, and struck but subsequently lost. When a whale is taken, the biologists attempt to obtain measurements, collect specimen material for sex and age determination, and take photographs. In addition, they observe whaling methods and equipment as a first step toward determining if it is possible to reduce the number of whales struck but not recovered.

In 1976, NMFS research was expanded with funding from the Outer Continental Shelf Environmental Assessment Program (OCSEAP) to determine the abundance, distribution, and movement of bowhead whales. (OCSEAP is a NOAA program funded by the Bureau of Land Management, U.S. Department of the Interior.) Aerial surveys were conducted to study offshore distribution and migration; ice-based observation stations were established to carry out 24-hour counts on the number of whales using near-shore leads during the spring migration. Although data collected by the OCSEAP study are contained in periodic reports published by that program (Fiscus et al., 1976; Braham and Krogman[1]), information pertinent to the harvest is included in this report.

ESKIMO WHALING METHODS

The methods used by present-day Alaskan Eskimos to take whales has evolved from ancestral hunts and from the adoption of commercial whaling gear and methods introduced by Yankee whalers in the last century (Fig. 2-6). Van Stone (1958) described the

[1]Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whales in the Bering, Chukchi, and Beaufort Seas. Unpubl. rep., 29 p. Natl. Mar. Fish. Serv., Northwest and Alaska Fisheries Center, Seattle, Wash.

era of commercial bowhead whaling in Alaskan waters. The most recent description of the development of current Eskimo whaling methods is that of Durham (1973). Van Stone (1962) describes the traditional method of marking and cutting shares from a whale carcass at Point Hope which, with some modification, is still in use. A similar, though much simplified, method of marking and cutting shares from whales is used at Barrow.

A description of whaling crews and current whaling methods and equipment employed in the fishery was presented in previous reports on the Eskimo harvest of bowhead whales (Marquette, 1976; Fiscus and Marquette[2]). The cost of maintaining and replacing whaling equipment, which is becoming increasingly expensive, is borne primarily by the whaling captains. Whaling gear used by the 14 crews at Point Hope is listed in Table 1.

Four new umiaks (skin boats) were constructed during the 1975-76 winter and used for spring whaling at Point Hope in 1976. One umiak was constructed at Kotzebue and transported to Point Hope in early spring by snowmobile and sled, a 4-day trip. Although all umiaks are of the same general dimensions and appearance, slight variations in materials and construction techniques make each boat distinctive.

In 1976 the price of a shoulder gun at the Point Hope store was $647, darting guns were $367.05 each, and a harpoon cost $33.25. At least three villagers own block and tackle sets capable of hauling whales out of the water onto the ice for butchering. Because the lines of one set were old and weak and broke frequently during use, much time was spent repairing them, which slowed the butchering process considerably. Each set of block and tackle is valued at about $1,500, and use of his equipment to remove a whale from the water entitles the owner to a share of that animal.

Figure 3.—An 100-year old shoulder gun. Guns of a similar type, with slight modification, are used today to kill bowhead whales.

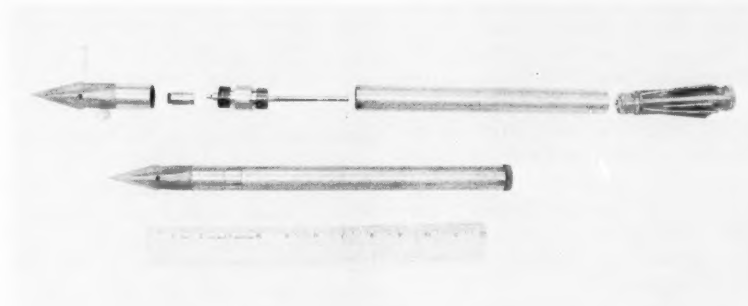


Figure 4.—Expanded view of bomb used in shoulder guns. Bomb fired from darting gun (bottom) is identical except it is about 8 cm (3 inches) shorter because flight-vanes are not needed.

In Barrow, large plastic floats (38-51 cm; 15-20 inches) that are attached to the harpoon lines to mark the whale's location were selling for $42.50, and the small floats (30-36 cm; 12-14 inches) that are attached by a line to the darting guns to keep them from sinking were priced at $16.75 each. At least two individuals own block and tackle sets.

UTILIZATION OF WHALES

The whales were pulled from the water when possible with a block and tackle and then butchered. Thin ice required partial butchering of the animal before it could be hauled from the water, a situation that greatly increased the time spent on this aspect of whaling. Accordingly, the butchering process required from as few as 3 to as many as 30 hours. Parts removed from the animal were taken ashore as soon as possible to prevent loss when the ice shifted (Fig. 7, 8).

Most of the meat, muktuk (skin with

[2]Fiscus, C. H., and W. M. Marquette. 1975. National Marine Fisheries Service field studies relating to the bowhead whale harvest in Alaska 1974. Unpubl. rep., 23 p. Natl. Mar. Fish. Serv., Northwest and Alaska Fisheries Center, Seattle, Wash.

Figure 5.—Harpoon with toggle-head in position for thrusting into whale.

Figure 6.—Harpoon head rotated to position illustrated as result of tension caused by attached line and float, after harpoon has entered body of the whale. The toggle-head greatly reduces chance that the harpoon may be pulled out, perhaps resulting in loss of the whale.

Table 1.—Type of equipment used by whaling crews at Point Hope, Alaska, spring 1976. Each horizontal line refers to the equipment of one crew. Bottom line is total equipment.

			Darting gun		Floats		
Boat (umiak)	Outboard motor	Shoulder gun	With harpoon	Without harpoon	Large plastic	Small plastic	Sealskin
1	0	1	1	0	0	1	1
1	0	1	1	1	0	1	1
1	0	2	1	1	1	1	0
1	1	2	[1]1	[2]1	1	1	0
1	0	0	1	1	1	1	0
1	0	0	1	1	1	1	0
1	1	2	1	1	1	1	0
1	0	1	1	1	1	1	0
1	0	1	1	1	1	1	0
1	0	1	1	0	1	1	0
1	1	0	1	1	1	1	0
1	0	1	1	1	1	1	0
1	1	1	1	1	1	1	0
1	0	0	1	1	1	1	0
14	4	13	14	12	12	14	2

[1]Lost taking whale on 3 May, replacement purchased.
[2]Lost taking whale on 3 May.

equal thickness of blubber), and blubber were removed from the butchering site immediately after the whale was cut up. Occasionally, however, several days elapsed before all shares were removed. Remains of the backbone, some internal organs, and the skull (at Barrow) were generally left on the site. Usually, fewer parts of the whale were left on the ice at Point Hope than at Barrow. At Point Hope, the skull was returned to the sea after the tympanic bullae and lower jawbones were removed, and the latter were taken to the village. At Barrow, the skull (tympanic bullae removed), including jawbones, was usually left at the butchering site. At some butchering sites, mostly at Barrow, blubber was left on the ice. Before the snowmobile era, surplus blubber was used for dog feed. The Eskimo utilizes most of the whale, including the meat, muktuk, baleen, gum tissue (mamaak), flukes, flippers, brain, tongue, intestines, heart, kidneys, epithelium of the liver, the tympanic bullae, and frequently the stomach (Carroll, 1976).

Whales taken several days after death are called stinkers. The muktuk (skin and blubber), flukes, flippers, and baleen of a stinker can be salvaged, but the remainder must be discarded as inedible. Normally, the crew responsible for the death of a stinker can be identified from marks on the harpoon or from bomb particles embedded in the whale. If so, the crew that recovers the animal shares the carcass with the crew that killed it. Otherwise, a stinker belongs to the recovering crew.

SPRING WHALING

Whaling Villages

St. Lawrence Island

The 1976 whaling season began on St. Lawrence Island about 1 April and ended about 20 May. Some 19 crews from Gambell and at least 3 crews from Savoonga actively whaled during the spring. The first whale harvested by St. Lawrence Island crews was taken 21 April. One bowhead was taken by Gambell whalers, and seven whales were reported taken by Savoonga crews (Table 2). One of the latter was a stinker. Five additional whales were reported struck but lost off St. Lawrence Island. The bowhead whaling season here ends when conditions become favorable for walrus, *Odobenus rosmarus*, hunting, and, although whaling gear is carried in the boats, few bowheads are taken after the hunting of walrus has begun. The people of Gambell and Savoonga share their whale catch each year.

One whaling captain from Savoonga reported that during the whaling season he believed that most of the whales passed north in the morning, between the hours of 0500 and 0800, and that only a few traveled north throughout the day. He also reported that an unusually large number of bowheads was observed migrating northward in the spring of 1976.

Figure 7.—Skin-deep cuts are made by a skilled flensor before whale is removed from the water to indicate how specific sections of the whale are to be cut and removed.

Figure 8.—Two large whales pulled onto the ice for butchering.

Table 2.—Biological features of bowhead whales taken during spring 1976.

Area and date	Length (cm)	Sex	Remarks
St. Lawrence Is.-Gambell			
—	—	—	One taken, no data available
Savoonga			
—	[1]914	F	
—	[1]1,067	M	
—	[1]610	M	
—	[1]762	M	
—	[1]914	M	
—	[1]853	M	
—	—	—	One taken, no data available
Kivalina	—	—	None taken
Point Hope			
23 April	[1]792	—	
1 May	1,021	M	
2	1,321	F	
2	1,120	M	
2	853	F	
3	1,468	M	
3	846	F	
3	848	F	
6	825	F	Ingutuk[2] Stinker[3]
7	889	F	
9	808	F	
14	762	M	
Wainwright			
—	—	—	One taken, no data available
4 June	—	—	
4	—	—	
Barrow			
2 May	[4]750	M	
5	1,144	M	
6	796	—	
6	1,136	—	
6	750	F	
9	1,235	M	Stinker
11	980	M	Stinker
12	1,370	M	Stinker
14	1,070	M	Stinker
15	1,100	M	
15	[4]685	F	
17	854	F	Ingutuk
19	1,158	F	Stinker

[1]Estimate of length in feet was provided by the Eskimos.
[2]Small whales that are especially fat are designated as Ingutuk by the Eskimos.
[3]Whales recovered several days after death are called stinkers.
[4]Length based on measuring segments of butchered whale.

Wales

Two crews were active during the spring of 1976 at the village of Wales. No whales were taken, and none was struck and lost. The period of whaling approximated that of Point Hope, although the exact dates are not known.

Kivalina

Three crews actively whaled at Kivalina during the spring of 1976. Whales were neither taken nor struck. The period of whaling at Kivalina approximated that of Point Hope, although the exact dates are not known.

Point Hope

The whaling season began 10 April and ended 28 May when the ice became unsafe. NMFS observers were stationed in the village from 28 April until 1 June to monitor the harvest.

Fourteen whaling crews at Point Hope took 12 whales in 1976, and biological information was collected by NMFS observers from 11 (Table 2). Eight of the whales were young animals less than 8.9 m (29 feet, 2 inches) in length, and four were older animals 10.2 m (33 feet, 6 inches) or over in length. The largest whale taken at Point Hope was 14.7 m (48 feet, 2 inches) in length. Although no whales were reported killed and lost at Point Hope, 12 were struck and lost there.

During the 1976 season 235 bowhead whales were sighted at Point Hope (Table 3). Bowheads taken by the whalers were included in the total and every effort was made to eliminate duplicate reports of sightings. Because other whales may have been seen by

Table 3.—Sightings of bowhead whales, spring 1976.

	Location			Location	
Date	Point Hope	Barrow[1]	Date	Point Hope	Barrow[1]
April			14	5	5
10-23	15	0	15	0	14
24	—	0	16	3	29
25	—	5	17	3	35
26	—	0			
27	—	0	18	0	61
28	[2]4	0	19	0	1
29	0	17	20	0	0
30	25	17	21	3	4
May			22	3	19
1	107	20	23	6	0
2	7	9	24	0	9
3	5	2	25	0	1
4	0	0	26	0	6
5	7	20	27	0	0
6	13	35	28	0	0
7	8	9	29	0	0
8	0	5	30	0	0
9	9	2	31	0	1
10	0	1	June		
11	0	0	1	0	1
12	0	0	2	—	1
13	12	28	Totals	235	357

[1]Data from Fiscus et al., 1976. (Corrected figures provided by H. Braham, pers. commun.)
[2]Observed from aircraft on flight from Barrow to Point Hope.

crew members and not reported, the 235 sightings represent a minimum number of bowheads seen at Point Hope.

Wainwright

Eight whaling crews were reported to be active during the spring of 1976 at the village of Wainwright. Three whales were taken but information was not received on animals that may have been struck and lost. The whaling period at Wainwright approximates that of Barrow.

Barrow

The whaling season began about 20 April 1976 and ended 2 June when the ice became unsafe for travel. Two NMFS harvest monitoring observers were stationed at the Naval Arctic Research Laboratory (NARL), Barrow, from 22 April to 3 June. In addition, an OCSEAP crew of four was stationed on the ice at the edge of the lead to make observations of bowhead whales and other marine mammals throughout the whaling season.

The number of whaling crews actively engaged in whaling varied almost daily, but approximately 36 of them operated at Barrow some time during the season. Thirteen whales were taken and recovered during the spring season. Five of the 13 whales recovered were stinkers, the highest number recorded during a single season since NMFS began monitoring the harvest. In addition, 18 were reported struck and lost, and 7 more were killed and lost. Two additional bowheads may have been killed and lost, which would bring the total to 22. The latter two were sighted from the air by OCSEAP scientists (H. Braham, Marine Mammal Division, Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, WA 98115, pers. commun.). One dead whale was sighted 24 May floating among the ice floes 46 km (28.5 miles) south of Barrow and about 28-37 km (17-23 miles) offshore. On 22 May, the aerial crew observed 34 polar bears, *Ursus maritimus*, on the ice feeding upon what appeared to be a whale carcass under the ice, judging from the amount of debris in the area and the size of the stained area on the ice.

Some data were obtained on each of the butchered whales (Table 2). Body lengths of the whales taken ranged from 6.8 to 13.7 m (22 feet, 6 inches to 45 feet). Six of the whales were young animals less than 9.8 m (32 feet, 2 inches) in length, and seven were older animals 10.7 m (35 feet, 1 inch) or more in length. The largest whale taken at Barrow was 13.7 m (45 feet) in length.

We collected information on Point Hope and Barrow and indirectly learned of whaling activities at other villages from various sources. John J. Burns, Alaska Department of Fish and Game, Nome, and Milstead C. Zahn, NMFS, Alaska Region, Juneau, supplied information from St. Lawrence Island. Toby Anungazuk, Alaska Department of Fish and Game, Wales, supplied information about whaling at that village. Clinton Swan provided information on whaling at Kivalina.

Whaling Effort

More crews were engaged in bowhead whaling in 1976 than in 1975. The number increased from 13 to 14 at Point Hope, from 4 to 8 at Wainwright, and from 30 to 36 at Barrow. Although a large number of crews are outfitted with whaling gear, the number that actively engage in whaling throughout the season is significantly smaller. At Kivalina only three crews were reported to have whaled in the spring of 1976, two less than reported for 1975. Two crews were actively whaling at Wales, and 23 were reported to be on St. Lawrence Island in 1976, a figure similar to that of 1975. At least 86 crews were, therefore, engaged in whaling in the spring of 1976.

Since the number of crews hunting at the lead varies daily, we maintain a record of their activities throughout the season in an attempt to evaluate hunting effort (Tables 4 and 5). In 1976, Point Hope crews were at the lead 23 days (66 percent of the time) from 28 April to 1 June. At Barrow, crews were at the lead

Table 4.—Whaling effort at Point Hope, Alaska, spring 1976.

Date	Number of crews on lead	Remarks
April		
28	0	Lead closed
29	0	Lead closed
30	14	Lead opened at 1200 hours
May		
1	14	Lead open
2	14	Lead open
3	14	Lead open
4	14	Lead open
5	14	Lead open
6	10	Lead open, several miles wide
7	12	Lead open, several miles wide
8	13	Lead open, several miles wide
9	14	Lead open, all crews off ice 2400 hours, windy
10	0	Lead open, windy and rough
11	8	Lead open, windy and rough
12	10	Lead open
13	14	Lead open
14	12	Lead open
15	6	Most of lead closed, open on East end
16	3	Most of lead closed, open on East end, raining
17	4	Most of lead closed, open on East end, raining
18	0	Lead open, windy and rough, ice dangerous
19	0	Lead open, windy and rough, ice dangerous
20	0	Lead open, windy and rough, ice dangerous
21	7	Lead open
22	13	Lead open
23	13	Lead open
24	1	Lead open, windy and rough
25	0	Lead open, windy and rough
26	0	Lead closed
27	3	Scattered openings
28	2	Lead open, windy and rough
29	0	Lead open, windy, strong current, ice dangerous
30	0	Lead open, windy, strong current, ice dangerous
31	0	Lead open, windy, strong current, ice dangerous
June		
1	0	End of season

31 days (72 percent of the time) from 22 April to 3 June. Weather conditions at Barrow during this period are presented in Table 6.

Whaling effort of the crews at the two villages was evaluated by examining the number of crew-days required to take a whale. Expressed as the number of crews that whaled each day, Point Hope crews whaled a total of 229 crew-days for an average of 6.5 crews per day, and Barrow crews whaled 314 crew-days, an average of 7.3 crews per day during the season. Since 12 whales were taken at Point Hope, 19.1 crew-days were required for each whale recovered. At Barrow, 24.2 crew-days were required to take each of 13 whales during the spring harvest. A comparison of crew-days required to take whales indicates that the Point Hope whalers expended slightly less effort to take whales than the whalers at Barrow. Whaling effort required to take whales during a season may indicate differential effects of the climate, ice, and ocean currents on the ability of the whalers to kill and recover bowhead whales.

Although the total number of crews engaged in whaling in the spring of 1976 at Barrow was large, the number that participated at every opportunity throughout the season averaged close to 11. A daily count of active crews was not obtained because camps were scattered along 40 km (25 miles) of lead and not all could be reached during a single day. The whaling season lasted about a month and a half at Point Hope and Barrow, and the most productive hunting occurred during May.

Table 5.—Whaling effort at Barrow, Alaska, spring 1976.

Date	Number of crews on lead	Remarks
April		
22	3	Lead opening and closing
23	6	Lead closed
24	0	Lead closed
25	0	Lead closed
26	10	Lead closed
27	0	Lead closed
28	0	Lead closed
29	7	Lead open
30	13	Lead open
May		
1	15	South lead closed, north lead open
2	10	North lead open, windy and rough
3	13	Lead open, ice dangerous
4	0	Lead open, ice dangerous
5	20	Lead open
6	22	Lead open, windy and rough
7	0	Lead open, windy and rough
8	20	Lead freezing over
9	0	Lead closed
10	0	Lead closed
11	0	Lead closed
12	0	Lead closed
13	10	Variable openings
14	15	Variable openings
15	28	Lead open
16	27	Lead open
17	27	Lead open
18	20	Lead closing
19	10	Scattered openings
20	5	Scattered openings
21	5	Scattered openings
22	5	Scattered openings
23	5	Scattered openings
24	5	Scattered openings
25	2	Scattered openings
26	2	Lead closing
27	2	Lead closed
28	2	Lead closed
29	0	Lead closed
30	1	Ice breaking up
31	1	Ice dangerous
June		
1	2	Ice dangerous
2	1	Ice dangerous
3	0	Season ended

Table 6.—Weather data at Barrow, Alaska, spring 1976.

Date	Temperature (°F) Max.	Min.	Avg.	Average wind velocity (mph)	Wind direction (degrees)
April					
22	10	−9	1	6.8	090
23	11	5	8	5.3	340
24	10	6	8	8.2	090
25	16	5	10	9.0	100
26	18	4	11	8.2	090
27	15	−1	7	6.1	250
28	14	−12	1	9.6	140
29	19	−6	7	14.3	100
30	23	10	17	12.5	090
May					
1	23	9	16	11.6	080
2	25	15	20	13.2	060
3	28	15	22	18.7	070
4	30	22	26	16.5	070
5	30	16	23	6.3	200
6	27	14	21	13.6	060
7	16	9	13	15.8	060
8	14	6	10	8.6	020
9	13	2	8	8.2	060
10	10	1	6	7.2	060
11	9	3	6	5.7	060
12	14	9	12	11.3	070
13	15	4	10	14.0	070
14	13	4	9	12.5	060
15	15	10	13	12.9	090
16	21	13	17	15.2	080
17	16	9	13	15.6	070
18	11	8	10	12.5	080
19	11	7	9	7.6	290
20	17	10	14	5.4	090
21	15	11	13	10.2	090
22	20	11	16	14.6	080
23	23	19	21	12.1	080
24	27	23	25	12.3	030
25	30	23	27	11.2	020
26	29	19	24	12.4	230
27	25	13	19	9.3	220
28	30	22	26	11.2	020
29	30	25	28	14.0	010
30	35	28	32	11.6	070
31	34	26	30	11.9	110
June					
1	34	23	28	10.0	080

Other Mammals

In addition to bowhead whales, the following species of mammals were observed or reported in 1976 at Point Hope during the spring whaling season: belukha; bearded seal, *Erignathus barbatus;* largha seal, *Phoca largha;* ringed seal, *Phoca hispida;* polar bear; and walrus.

Belukha were observed from 28 April to 22 May at Point Hope. At least two noticeable waves of these animals migrated past the whaling camps. The first occurred from late April to 5 May and the second from 8 to 16 May. A third wave may have occurred in late May. Belukha sighted and taken at Point Hope are given in Table 7.

Although they are prized for food, the whalers do not actively pursue belukha during the bowhead whaling season because they frequently sink quickly and require considerable effort to recover. A belukha harvest at this time is incidental to the bowhead whale fishery. Rifles are normally used to kill the animals and those that sink are recovered with a grapple. It is difficult to obtain data on the belukha because these animals are butchered immediately after they are killed, a process that requires but a few minutes to complete after the animal is hauled onto the ice. Crew members at times eat some of the meat at the whaling camp but usually take their shares directly home.

Other species killed at Point Hope during the spring of 1976 (Table 8) included 77 ringed seals and 1 largha seal. Two bearded seals were sighted but not killed. A dead floating walrus was found drifting in the lead by the whalers but was not taken. Two polar bears were sighted from an aircraft on a flight from Barrow to Point Hope.

At Barrow, other species killed included two belukha (Table 7), one of which sank and was lost, and four polar bears (Table 9). A total of 328 belukha was sighted: 19 on 16 May, 101 on 18 May, and 208 on 22 May (Table 7). Sightings of belukha at Barrow varied considerably, perhaps due to weather and ice conditions that made observa-

tions difficult. Belukha may utilize leads that are farther out than the nearshore leads frequented by whalers, as indicated by OCSEAP surveys (Fiscus et al., 1976; footnote 1). In addition to 34 polar bears counted feeding upon a large carcass frozen in the ice north of Barrow, other marine mammals observed during aerial surveys of the northeastern Chukchi and western Beaufort Seas by OCSEAP observers from 30 April to 20 June are reported by Fiscus et al. (1976).

At Wales, three belukha were reported taken by two crews during the spring season (Table 7).

Narwhals, *Monodon monoceros*, have been reported as occasional visitors to Alaskan waters (Geist et al., 1960). An experienced whaling captain at Barrow reported that he sighted a single narwhal in a pod of belukha on 15 May west of the village.

An unconfirmed occurrence of a narwhal stranding on the coast near Point Hope a few years ago was noted in a recent report (Marquette[3]). It was subsequently established that John Bockstoce had investigated the stranding in April 1972 and he has kindly permitted publication of the details. The carcass of the narwhal, a male, was found beached in late October 1971 about 8 km (5 miles) north of Point Hope, by a village resident. He reported that its body was about 2.75 to 3 m (9 to 10 feet) long, with a tusk of about 1 m (39 inches) in length. The narwhal had apparently died from a bullet wound at the base of the cranium. The tusk was removed by the finder and was later sold to a visitor to the village.

A resident of Barrow stated that he sighted killer, *Orcinus orca*, and gray, *Eschrichtius robustus*, whales while traveling to Wainwright by boat during the first week of September. Killer whales apparently appear occasionally in Alaskan arctic waters. Bee and Hall (1956) noted three records (one near Icy Cape and two near Barrow) of these whales in the area. Banfield (1974) stated that they are rare visitors to the Beaufort Sea.

Two incidents of killer whales attacking other cetaceans were reported by Eskimos in 1976. In August 1975, four Point Hope residents on a boat a short distance south of the village observed seven killer whales attacking a young gray whale. They reported that the largest killer whale held the gray by the tail while the others attacked various areas of the gray's body. After a short time the killer whales appeared to abandon the gray, which was almost motionless and bleeding profusely. After remaining almost lifeless for several minutes the gray began to feebly swim away when the killer whales suddenly reappeared and attacked it again. The gray soon sank from sight and presumably died. At Barrow, three residents witnessed three or four killer whales attacking an unidentified cetacean off the coast of that village during the summer of 1976.

[3]Marquette, W. M. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973-1976, and a biological summary of the species. Unpubl. rep., 80 p. Natl. Mar. Fish. Serv., Northwest and Alaska Fisheries Center, Seattle, Wash.

Table 7.—Belukha taken or observed at whaling villages in Alaska during spring, 1976.

Location and date	Number sighted	Killed and recovered	Killed but lost	Remarks
Point Hope				
28 April	321	0	0	Observed from aircraft on flight from Barrow to Point Hope
1 May	26	0	0	
2	1	1	0	
3	150	1	0	
5	10	0	0	
6	1	0	0	
7	1	1	0	
8	15	0	0	
9	4	4	0	
11	100	0	0	
13	250	0	0	
14	1	1	0	Male 423 cm long, skull taken for Marine Mammal Division collection
16	12	0	0	
17	1	0	0	
22	35	0	0	
Total	928	8	0	
Barrow[1]				
16 May	19	0	0	
18	101	0	1	Sank
22	208	1	0	
Total	328	1	1	
Wales				
	3	3		
Total	3	3		

[1]Data combined for harvest and OCSEAP crews.

AUTUMN WHALING

Barrow

The beginning of the autumn whaling season coincides with the westward migration of bowheads past Barrow to wintering grounds in the Bering Sea. In 1976 the whaling season began 26 August, which was unusually early for Barrow, and ended 8 October when the formation of new ice prevented further travel by boat. Weather data for Barrow during this period are given in Table 10. The pack ice remained approximately 104.6 km (65 miles) off the north coast of Alaska during the autumn whaling season. An NMFS observer was stationed at NARL from 11 September to 14 October.

Autumn whaling differs in several ways from spring whaling. Wood or aluminum boats, from 5.49 to 7.62 m (18 to 25 feet) in length, are used instead of skin-covered boats. The crews often must venture several miles out to sea to locate the whales. The boats are powered by large outboard or inboard

Table 8.—Mammals other than whales taken or observed at Point Hope, Alaska, spring 1976.

Species	Date	Number sighted[1]	Number killed	Sex	Length	Remarks
Ringed seal	24 Feb.-7 Mar.		1	M		
	24 Feb.-7 Mar.		1	M		
	24 Feb.-7 Mar.		1			
	7-19 Mar.		1	M	118.6	
	12-19 April		1			
	12-19		1	M		
	12-19		1	M		
	12-19		1	M		
	16-21		1	F		
	16-21		1	M		
	16-21		1	M		
	16-21		1	M		
	16-21		1			
	16-21		1	M		
	16-21		1	M		
	16-21		1	M		
	16-21		1	M		
	16-21		1	M		
	16-21		1	M		
	16-23		1	M		
	16-23		1	M		
	16-27		1	M		
	18 Apr.-2 May		7			
	24-27 April		2	M		
	24-30		1	M		
	25		1	M		
	30		1	M		
	1 May		1	M	126.9	
	1		10			
	6		10			
	13		1	M	123.7	
	13		1	M	126.0	
	16		1	M	117.4	
	17		3			
	27		5	M		
	27		1	F		
	27		1	F	126.6	
	27		1	M	106.6	
	27		1	F	106.1	
	27		1	F	102.6	
	27		1	M	120.8	
	27		1	M	108.3	
	27		1	F	101.2	
	27		1	F	107.0	
	27		1	M	112.2	
	27		1	M	112.5	
Bearded seal	1 May	1	0			
	31	1	0			
Largha seal	1 May	1	1			
Polar bear	28 Apr.	2	0			Observed from aircraft on flight from Barrow to Point Hope
Walrus	12 May	1 (dead)	0			Found floating in lead, not taken

[1] Information on total number of ringed seals sighted was not obtained. Information on ringed seal was obtained by Glenn Seaman, Fairbanks, Alaska, during cooperative studies with Alaska Department of Fish and Game.

Table 9.—Mammals other than whales killed or observed at Barrow, Alaska, spring 1976.

Species	Date	Number sighted	Number taken
Polar bear	14 May	1	0
	31	1	1
	31	1	1
	31	1	1
	31	1	1
		5	4

Table 10.—Weather data at Barrow, Alaska, during autumn whaling season 1976.

Date	Temperature (°F) Max.	Min.	Avg.	Avg. wind velocity (mph)	Wind direction (degrees)
Aug.					
26	46	34	40	14.2	090
27	41	33	37	10.6	080
28	42	33	38	6.0	100
29	48	33	41	5.8	120
30	43	36	40	6.0	150
31	51	35	43	6.5	100
Sept.					
1	37	34	36	4.4	330
2	37	31	34	4.2	310
3	33	30	32	7.8	300
4	36	28	32	8.6	260
5	35	26	31	6.7	190
6	37	31	34	8.9	160
7	44	33	39	11.1	180
8	34	31	33	9.3	020
9	36	33	35	5.4	070
10	38	32	35	8.7	120
11	48	33	41	13.5	120
12	34	30	32	11.8	100
13	33	31	32	11.4	080
14	36	32	34	17.3	070
15	35	33	34	13.9	060
16	35	32	34	6.9	060
17	35	31	33	10.4	100
18	35	30	33	12.4	100
19	33	29	31	8.3	080
20	31	23	27	9.2	080
21	46	31	39	15.2	190
22	39	32	36	10.4	230
23	34	29	32	14.9	060
24	31	27	29	14.6	070
25	30	27	29	14.9	070
26	33	30	32	7.8	050
27	32	28	30	9.3	080
28	31	27	29	18.5	040
29	29	22	26	19.9	050
30	22	18	20	19.5	070
Oct.					
1	24	19	22	18.1	080
2	27	18	23	15.2	090
3	26	23	25	15.2	040
4	25	23	24	16.4	040
5	27	23	25	18.4	070
6	28	22	25	15.1	070
7	28	21	25	7.7	070
8	26	21	24	14.6	230
9	24	4	14	16.6	240
10	19	0	10	15.5	220

motors; noise made by these motors apparently does not frighten the animals in the autumn as it does during the spring hunt, according to reports by the whalers. As in the spring, darting and shoulder guns are used in the autumn to kill the whales. However, since the migrating whales are usually hunted in the open sea during the autumn, they are unable to escape easily by swimming under nearby ice floes as they frequently do in the spring. The whalers are therefore able to pursue them for a longer time until they are killed.

Twelve crews engaged in autumn whaling at Barrow killed and recovered 10 whales. An 11th whale was killed but abandoned because of rough seas and an insufficient number of boats to assist in safely towing the carcass to shore some 46 km (25 miles) away. The whalers reported that most of the whales were taken about 37 km (23 miles) north of Point Barrow. From 15 to 32 hours were required to tow the whales to shore near the village. Data obtained on whales that were killed and recovered are presented in Table 11.

Although the whalers prefer to kill the small whales that are reported to follow the earlier migrating large animals, the 10 whales taken this autumn were all large and measured from 13.20 to 17.30 m (43 feet, 4 inches to 56 feet, 9 inches) in length. This year is the first in

Table 11.—Biological features of bowhead whales taken during autumn 1976 by Alaskan Eskimos.

Area and date	Length (cm)	Sex	Remarks
Barrow			
28 Aug.	[1]1,650	M	
30	[1]1,630	M	
3 Sept.	[1]1,620	M	
3	[1]1,650	M	
3	[1]1,730	F	131-cm fetus collected
10	1,600	F	Ingutuvak[2]
20	1,430	F	
20	1,408	M	
20	1,525	M	
21			Lost due to high seas
7 Oct.	1,320	M	
Kaktovik			
20 Sept.	[1]1,371	M	
27	[1]914		
Nuiqsut			None taken

[1]Length estimated by natives.
[2]Whales that are especially fat and longer than the Ingutuk are designated by the Eskimos as Ingutuvak.

Table 12.—Alaskan Eskimo bowhead whaling data, 1976.

Season/Location	Number recovered	Number killed and lost	Number struck and lost
Spring			
Gambell	1	0	0
Savoonga	7	0	5
Wales	0	0	0
Kivalina	0	0	0
Point Hope	12	0	12
Wainwright	3	0	0
Barrow	13	7	18
Autumn			
Barrow	10	1	0
Nuiqsut	0	0	0
Kaktovik	2	0	0
Total	48	8	35

which bowheads have been reported taken in August at Barrow.

Nuiqsut

Three crews actively whaled during the autumn of 1976 at the village of Nuiqsut. A fourth crew could not join the hunt because of a malfunctioning motor. Whales were not taken, and information was not received on animals that may have been struck but lost.

Kaktovik

Seven whaling crews were active during the autumn of 1976 at the village of Kaktovik on Barter Island. Two bowheads were killed by Kaktovik crews, but information was not received on whales that may have been struck and lost.

SUMMARY

Details concerning the bowhead hunt in 1976 are give in Table 12. The fact that a whale is struck and lost does not necessarily mean that it has been fatally injured. Some whales harpooned with the darting gun escape when the line breaks, and others hit with a missile from the darting or shoulder gun escape if the bomb fails to explode. Some of the animals may die and some may recover.

In 1976, 35 whales were reported struck and lost and 8 were reported killed and lost for a total of 43 struck and lost. It should be noted, however, that since these data are obtained from statements made by the whalers, or rarely from the observations of investigators, they represent a minimum known number of animals struck and lost.

At the two villages (Point Hope and Barrow) where NMFS observers were stationed in the spring of 1976, 25 whales were killed and recovered—compared with 37 struck and lost. At Barrow 25 whales were struck and lost, of which 7 were reported killed and lost. Since 13 whales were killed and recovered, almost two animals were struck and lost for each one recovered. At Point Hope 24 whales were struck, of which 12 were killed and recovered and 12 were struck and lost. The Point Hope data are considered reasonably complete, whereas those for Barrow are incomplete due to the greater geographic dispersion of whalers in the locality.

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Signs Good for Gray, Bowhead Whale Conservation

There's good news for two depleted species of whales, according to NOAA Administrator Richard A. Frank.

The Pacific gray whale, once severely depleted because of commercial hunting in the last century, is now approaching its mid-1800's level of approximately 15,000 animals. And the most complete bowhead whale research program ever undertaken has indicated that more animals than expected — 2,264 — passed Point Barrow, Alaska, between 15 April and 30 May with others expected during June.

Frank, who is also U.S. Commissioner to the International Whaling Commission (IWC) said the Alaskan spring bowhead whale hunt ended with Eskimo whalers, operating for the first time under IWC regulation, landing 10 bowhead and striking but losing another 5. The quotas, established by the IWC and adopted by the United States, permitted the Eskimos to land 12 bowheads and strike 18, whichever occurred first. The two whales remaining in the 1978 quota were to be taken in the September and October hunts.

Pointing out that last year the Eskimos landed 29 bowheads and struck but lost another 82, Frank expressed his satisfaction with the outcome of the bowhead hunt, and his admiration for the manner in which Eskimo whalers and Alaskan officials conducted it. The spring season brought an unprecedented effort to hunt with new efficiency and to eliminate as far as possible wasteful wounding of the great animals, he said.

Praising Eskimo whalers for their performance during the spring hunt, Frank said, "the Eskimos entered the season with strong reservations, and with a concern for their traditions and food needs, but they accepted the necessity for quotas, complied with the quotas, and essentially regulated themselves. We all owe them a debt of gratitude."

Frank, who flew to Alaska at the height of the season to meet with Eskimo whalers and officials, cited the season as a prime example of cooperation. He praised the Alaska Eskimo Whaling Commission (AEWC), the Alaska Department of Fish and Game, and NOAA's own National Marine Fisheries Service (NMFS) for highly effective teamwork.

The AEWC, he pointed out, established communications between the whaling villages which united them in common purpose and provided them an active role in the making of decisions.

Frank said that Eskimo reporting officers and AEWC representatives worked daily with NMFS agents. "This relationship," he said, "must be credited with being largely responsible for the ultimate success of the program." The State of Alaska appropriated $250,000 to support the work of the AEWC.

The bowhead research program, costing $780,000, not only carried out the most comprehensive census of its kind in history but studied population dynamics and acoustic techniques. Analysis of population data, including figures for the summer and autumn months, will continue through the year, with final results anticipated in December.

The research program included an ice-based census camp designed to count whales going through a nearshore lead near Barrow, aerial surveys conducted at the site of the census camps to help validate observations made by ice-camp observers, and land camp observations of the early and late migration patterns of bowheads taken in conjunction with aerial and vessel surveys. Additionally, the value of active sonar and recordings as tools for determining the distribution and abundance of whales was explored.

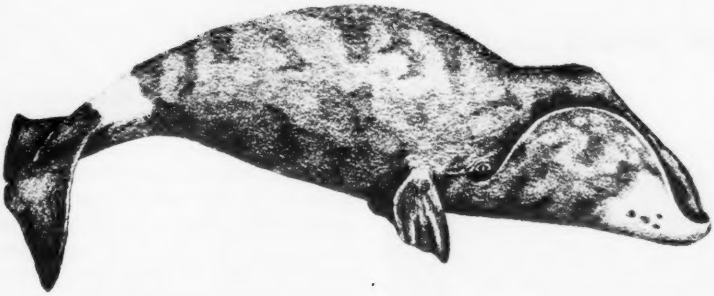
Researchers from the NMFS' Marine Mammal Division maintained a 24-hour observation schedule from two bases, the South and North Camps. Whales moved along the nearshore lead from South toward North Camp. Radio checks between bases served to increase accuracy.

The AEWC sponsored a whale counting camp manned by Barrow residents and assisted by two NMFS biologists. Eskimo whalers also participated independently. Observing conditions were excellent throughout the study.

Aerial surveys—174 hours—helped validate the census counts and delineate the spatial and temporal distribution of whales during migration. Researchers, employing an elaborate formula to correct figures for total observation time, duplicate sightings, and validation of animals believed to have been missed, offered a preliminary estimate of 1,783 whales at the lower end of the scale and 2,865 at the upper end, with 2,264 considered the best available estimate.

The gray whale, according to Frank, represents "a triumph of conservation. It vividly demonstrates that humankind can indeed protect endangered species, and that, once protected, they can recover." Ruthlessly exploited for more than a century, the gray whale has been on the IWC's protected list since 1946.

Frank cited a study conducted by Allen A. Wolman and Dale W. Rice of the NMFS. It showed a 1978 count indicating a total population of about 11,000, plus or minus 2,000 animals, as the whales passed southward off Monterey in California. In November and December 1977, other researchers counted gray whales leaving the Bering Sea at Unimak Pass, Alaska, and estimated a population of 15,120. NOAA officials, taking into account a variety of factors, estimate the probable population at between 11,000 and 15,000.



Above, bowhead whale. Illustration: Don Sineti. Left, California gray whale, showing baleen. NOAA photograph.

There are two geographically isolated stocks of gray whales: the eastern Pacific or California and the western Pacific or Asian.

The Asian stock summers in the northern Sea of Okhotsk and migrates down the Asian coast to calving grounds off the south coast of Korea. Its population is believed to be low, or it may even be extinct. The California stock summers in the northern Bering Sea, migrates down the North American coast, and winters off Mexico's west coast.

There is general agreement that the population did not exceed 15,000 prior to the initiation of exploitation in 1846.

After the IWC placed the gray whale on the protected list in 1946, intermittent counts were made. They indicated steadily increasing populations, for several years.

Starting in 1967-68, the Yankee Point-Grand Canyon site near Monterey was the scene of a winter shore count. There 95 percent of the whales pass within 2 km of shore, and boat traffic is at a minimum. The counts indicate a stable population.

Subsistence hunting by Eskimos is virtually nil on the American side, since the Eskimos prefer other stocks. On the Asiatic side, the gray whale catch is about 165 per year, taken by Soviets for their aboriginal people.

Frank said the Wolman-Rice report pointed to a potential problem for the California stock.

"The greatest threat . . . is increasing industrial development and vessel traffic in the calving lagoons," the report stated. "Considerable harassment is caused by commercial cruise boats which take people into the calving lagoons to seek the whales . . .

"Oil exploration is proceeding near some of the calving lagoons and may have an adverse effect on the habitat.

"In Scammon's Lagoon salt barges make daily trips and increasing visits by yachts, fishing boats, and small trailer-transported boats have occurred as well."

Program Compensates Fishermen for Losses

U.S. commercial fishermen whose vessels or gear are damaged or destroyed by foreign fishing vessels operating within the U.S. 200-mile fishery conservation zone will be eligible for compensation, the National Oceanic and Atmospheric Administration (NOAA) has announced. A system designed to reimburse fishermen quickly for any loss from incidents which occurred after 1 July 1976, has been instituted by NOAA's National Marine Fisheries Service (NMFS) to implement recent legislation.

Under the system, fishermen may apply for a loan if the replacement value of the damaged gear or vessel, less depreciation, exceeds $2,000. Loans will be made shortly after the application is received and approved by the NMFS, and will carry an interest rate of 3.5 percent.

After the loan is made, an effort will be made to determine who was at fault. If it is determined that the U.S. fisherman was not, the loan will be cancelled, all payments made on the loan will be refunded, and the fisherman will keep the loan funds as full compensation. If the U.S. fisherman was at fault, the loan will become due in full at an earlier—but still reasonable—date than originally set. If fault cannot be determined, the loan must be repaid according to the original terms which would correspond to the expected life of the equipment.

Presidential approval was also expected on a new program that would supercede the present compensation system, Fisheries officials said. Under that program, proposed to be effective 1 January 1979, fishermen would be paid for losses caused by foreign fishing vessels without regard to who was at fault. This program would not be retroactive.

Applications for the loan should be sent to the National Marine Fisheries Service, NOAA, F-25, Washington, DC. 20235. Assistance may be obtained from NMFS Regional Offices in Gloucester, Mass.; St. Petersburg, Fla.; Terminal Island, Calif.; Seattle, Wash.; and Juneau, Alaska.

Marine Impact of *Amoco Cadiz* Oil Spill Reviewed

Oil spilled by the wrecked supertanker *Amoco Cadiz* last March permeated the marine habitats of the Brittany shoreline to an unprecedented degree, a scientific report indicates. The oil's impact varied greatly with time after the spill, and was strongly influenced by the shape and nature of the shoreline involved, according to the report.

These were among preliminary findings of government and university scientists in their analysis of the largest oil spill in maritime history. The report, "The *Amoco Cadiz* Oil Spill — A Preliminary Scientific Report," was prepared by the National Oceanic and Atmospheric Administration in cooperation with the Environmental Protection Agency. A complete analysis of the incident could take several years.

"We had never seen biological damage of this geographic extent in any previous oil spill," Wilmot N. Hess, director of NOAA's Environmental Research Laboratories, said. Hess led the Commerce Department agency's scientific study for several weeks in France, and is editor of the NOAA/EPA report. By making the spill the subject of a major study, important new insights were gained into how oil moves and changes in the marine environment. The NOAA/EPA report presented the following preliminary findings.

1) Coastal processes and the shape and nature of shoreline played a major role in dispersing and accumulating oil.

2) About one-third of the 220,000 tons of spilled oil came ashore, and about two-thirds was lost to evaporation and the sea.

3) A significant amount of the spilled oil appeared to sink to the seafloor, where high concentrations were measured, and become dispersed in the vertical water column. The impact of this large-scale sinking on bottom life remains to be assessed.

4) An American index that helps estimate the vulnerability of various coastal environments to oil-spill damage worked well in the *Amoco Cadiz* incident, suggesting that it can be used as part of contingency plans for such similar, complex shorelines as those of Alaska and New England.

Amoco Cadiz wreck site off the Brittany Coast.

5) Several weeks after the spill, natural and human cleanup had reduced the amount of oil on the shoreline by an estimated 84 percent. However, a shift of winds from west to east, and the break up of large masses of oil offshore, extended contamination from the initial 43 miles (73 km) of shoreline to 192 miles (320 km) by late April, of which about 100 miles (180 km) were heavily oiled.

6) Contamination of ground water in the beaches by oil, or possibly by dispersants, appeared to be the main lethal factor in the large kills of intertidal organisms. Even after beaches had been extensively cleaned, the ground water between sand and sediment particles remained severely oiled.

7) Marine populations along 90 miles (150 km) of shoreline were stressed by the oil, with intertidal populations, as well as populations in marshlands and other enclosed areas, particularly hard hit. The adverse effects were amplified by high spring tides.

8) Many bird species were migrating to nesting grounds when the spill occurred, and some 3,200 dead birds, of more than 30 species, were counted. About 85 percent of these were shag cormorant, guillemot, razorbill, and puffin, the latter three considered rare or threatened in France. (Populations in the bird sanctuary at Sept Iles, greatly reduced by the *Torrey Canyon* spill in 1973, could be further reduced by oil from the *Amoco Cadiz*.)

9) The spill had major impacts on commercial marine product harvests, with the French seaweed industry affected to an uncertain extent, oyster mariculture operations hardhit, and lobster holding pens in the spill areas so thoroughly oiled that scientists say they could be out of service for a year. Little

The wreck of the *Amoco Cadiz*. NOAA photograph.

is known thus far of the spill's impact on commercial fin fisheries.

10) Hydrocarbons blown ashore by gale-force winds could have contaminated crops in the nearshore area, and could have entered the human food chain by adhering to plants consumed by food animals ashore. This kind of oil-spill side effect is not well understood.

11) The impact of an oil spill is greatly enlarged by the creation of a water-in-oil emulsion called a "mousse" (for its resemblance to chocolate pudding), the volume of which is about 2.5 times that of the spilled oil.

12) While it is generally recognized that dispersing oil on the high seas is the preferred method of handling a large spill, any contingency plan aimed at combatting a spill of this magnitude under conditions of high onshore winds and heavy seas must focus on attacking the oil on the beach. The longer the cleanup takes, the more deeply the spilled oil penetrates the coastal ecosystem, and the broader its impact is likely to be.

Glazer Named to Head NOAA Policy, Planning

Michael Glazer, former Chairman of the California Water Commission, has been appointed Assistant Administrator for Policy and Planning of the National Oceanic and Atmospheric Administration (NOAA). In announcing Glazer's new appointment in the Commerce Department agency, NOAA Administrator Richard A. Frank said the Policy and Planning job was one crucial to the mission of the Administration.

"Michael Glazer comes to NOAA," Frank said, "at a time when increasing pressures are being felt for balanced environmental programs on local, national, and worldwide scales. We are most fortunate to have someone so well qualified to help NOAA in its evolving oceanic and atmospheric programs of resource management and scientific services."

Glazer is a native of Los Angeles, receiving a B.S. degree in industrial engineering from Stanford University in 1962. He received a Master's degree from Harvard Graduate School of Business Administration in 1964, and a J.D. degree from the UCLA School of Law in 1967.

In 1968 he joined Tuttle and Taylor, a general business and securities law practice, representing a wide range of clients from publicly held corporations to Indian tribes. He was commissioner of the Los Angeles Department of Water and Power from 1973 to 1976, and served on the Blue Ribbon Committee on Water and Power Rate Restructuring for Los Angeles Mayor Tom Bradley. Earlier this year he entered Federal service as Special Assistant to the NOAA Administrator.

NOAA Fisheries Research Vessel Contract Issued

A $2,875,000 contract for a 127-foot research vessel has been awarded the Bender Shipbuilding Company[1] of Mobile, Ala., by the National Oceanic and Atmospheric Administration (NOAA). The multiple purpose fisheries research ship will be used for stock assessment in the north Pacific 200-mile fisheries zone.

The NOAA ship, to be delivered by September 1979, will be a modified stock design combination crabber/trawler, with accommodations for 17 crew members and scientists. The contract will be administered by the Maritime Administration, a component of the Commerce Department.

The research vessel, with a beam of approximately 30 feet and a 13-foot draft, will have a range of 6,000 miles at 11 knots. The power plant will deliver 1,250 shaft horsepower at 1,225 r.p.m. The ship will provide stock assessments as a basis for fishery management actions by using conventional types of commercial gear, including bottom trawls, midwater trawls, bottom and surface longlines, gill nets, and pot fishings. It will have two research laboratories, and an 8- × 20-foot portable scientific van. Two trawl winches, typical of this size commercial fishing vessel, will have a pull of about 20,000 pounds net, and each will be equipped with 1,000 fathoms of ¾-inch trawl wire.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

NOAA Grant Emphasizes Improvements in Fishery Communications

A special task force designed to improve communications among fishermen and fisheries organizations in the Northeast has been established by the New England Marine Advisory Service under a $59,200 grant awarded by the National Oceanic and Atmospheric Administration (NOAA). Recognizing that controversy exists among New England fishermen concerning limitations imposed under the 200-mile limit, the task force will focus much of its effort on resolving the issues, using workshops and other programs.

The advisory service also will strengthen its liaison with NOAA's National Marine Fisheries Service as well as the Northeast Regional Fisheries Management Council, which oversees fishing limits for both foreign and domestic fishermen under the 200-mile extended jurisdiction. The advisory service plans expanded use of Coast Guard and National Weather Service radio channels in providing information to fishermen, and hopes to use imagery from NOAA satellites to assist fishermen in locating fish.

An additional $30,800 in funds supplementing the Commerce Department agency grant has been pledged by the Sea Grant programs of the Massachusetts Institute of Technology, State University of New York/Cornell University, University of Maine, University of Massachusetts, University of New Hampshire, University of Rhode Island, New England Aquarium, New England Center for Continuing Education, and the Council of Presidents, Land Grant Universities of New England.

Sea Turtle Protection Plan Announced

A comprehensive program under the Endangered Species Act to prevent the extinction of the oceans' largest turtles—some weighing over 1,000 pounds—has been unveiled by the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce and the Department of the Interior's U.S. Fish and Wildlife Service. The program, announced by Richard A. Frank, Administrator of NOAA, will protect green, olive (Pacific) ridley, and loggerhead turtles by largely banning the intentional killing of these animals, prohibiting trade in turtle meat and products, and preserving habitat.

In recent years, dangerous declines in the numbers of sea turtles have resulted from destruction of habitats and commercial exploitation of the animals. "Condominium and apartment construction, opening up of new beaches for recreation, and other human activities have destroyed or put pressures on the traditional turtle nesting areas," Frank said. "Moreover, turtle meat is often considered a delicacy, as are turtle eggs, and products made from shell and hides have been in great demand. The survival of sea turtles depends upon lessening these pressures." In addition, Frank noted that turtles are taken incidentally in U.S. commercial fishing operations, particularly the Gulf and South Atlantic shrimp industry.

Frank stated that the new program will provide needed protection for the three species of sea turtles, "permitting them to survive and recover in the future." The new program includes the following elements:

1) Designation of green turtles with breeding grounds in Florida and the Pacific Coast of Mexico as endangered, and all other green turtles as threatened;

2) designation of olive ridley turtles breeding on the Pacific Coast of Mexico as endangered, and all other olive ridleys as threatened;

3) designation of loggerhead turtles throughout the world as threatened;

4) a stepped-up effort to develop excluder trawls that will permit fishermen to continue to catch shrimp while reducing the number of turtles accidentally caught in nets;

5) upcoming proposals to designate portions of the Cape Canaveral Ship Canal in Florida and nearshore areas of St. Croix, Virgin Islands, as critical habitats;

6) an expanded monitoring program with a view toward designation of additional areas for habitat protection;

7) a ban on the importation of turtle products from mariculture operations; and

8) a ban on subsistence taking of sea turtles except for limited taking in the Trust Territory of the Western Pacific.

A rare, white, 2-week-old loggerhead sea turtle hatched at Nova University's Ocean Science Center. NOAA photograph by Ralph F. Kresge.

The effect of the action is to prohibit trade in and the intentional taking of the three species of sea turtles, except for scientific research, public display, and the limited subsistence take in the Trust Territory. While some incidental taking of the sea turtles may continue in fishing operations, such operations are to be strictly regulated to preserve the species. Commercial interests that will be affected by the regulation include leather goods, food, cosmetics, and curio and jewelry concerns. A 1-year grace period will be allowed for interstate commerce to enable dealers, shopkeepers, and others to clear their shelves.

The green sea turtle, perhaps the most commercially valuable reptile in the world, is found in numerous areas around the globe, but has suffered a sharp drop in numbers. For example, NMFS scientists believe that the once abundant Florida population has now declined to less than 100 mature adults. The total world population of green sea turtles is believed to be no more than 600,000 adults.

Olive ridley turtles, which are not known to nest in the continental United States, have been taken commercially at the rate of between 500,000 and 1,000,000 annually since the 1960's. In one area of Mexico, females were reportedly taken last year from a population estimated to be 150,000. Scientists say that the stocks are beginning to show stress, and that if the take continues at the present rate, stocks may be beyond recovery in as few as 8 years. The olive ridley is hunted primarily for turtle leather.

Loggerhead turtles, like green turtles, are found throughout the world. They are estimated to number between 25,000 and 50,000 in the United States, but are not now in immediate danger of extinction. They are exploited for their meat, for soup, and for other products.

Three other species of sea turtles, the Atlantic ridley, leatherback, and hawksbill, are already listed as endangered. The Department of Commerce has jurisdiction over sea turtles from the edge of the water seaward and the Department of the Interior has jurisdiction on land.

The Soviet Whaling Industry, 1970-77

The Soviet Union became the world's leading whaling nation in the 1970's. During the 1977-76 Antarctic and 1976 North Pacific whaling seasons, the Soviet Union caught a total of 11,560 large and 3,034 small whales (Tables 1 and 2). Its catch of large whales was roughly 70 percent of the total world catch and more than triple the catch of its closest competitor, Japan. Its catch of small whales in 1976 was only slightly less than Japan's and in each of the previous three seasons was about 25 percent of the total world catch.

CATCH AND GROUNDS

In the 1970's, the four Soviet expeditionary whaling fleets have harvested four species of large whales: Fin[1], sei, Bryde's, and sperm. Of the four, sperm whales have made up the largest proportion of the annual catches. In the 1975-76 Antarctic and 1976 North Pacific season, sperm whales accounted for 88 percent of the total catch. Table 3 shows the species breakdowns for the 1975 and 1976 catches in all areas and includes provisional data for the 1976-77 Antarctic season. The category "other" under large whales shows the catch of gray whales by the native coastal fishery.

The annual Soviet catches of large whales, broken down by areas, are given in Tables 4 and 5. In 1976, the North Pacific and Bering Sea pelagic fisheries provided 38 percent of the total catch. (The total figure for the Southern Hemisphere includes the catches from the Antarctic pelagic fishery as well as the numbers caught during transit to and from the Antarctic through the South Atlantic, South Pacific, and Indian Ocean.)

The Soviet catch of fin, sei, and Bryde's whales is quite small in comparison with the total catch of sperm whales. In 1976, the catch of fin and sei whales decreased both proportionally and absolutely relative to the total catch as a result of reduced International Whaling Commission (IWC) quotas (Table 4). The catch of fin whales decreased from 414 in 1975 to 88 in 1976, or from 3 percent to 1 percent of the total catch; the catch of sei whales decreased from 1,632 to 505, or from 11 to 4 percent. In 1976, the catch of fin and sei whales was taken entirely from the Antarctic grounds, whereas in the previous season small numbers of each were also taken in the North Pacific Ocean and the Barents Sea. The catch of Bryde's whales in the North Pacific and the Barents Sea increased slightly from 629 in 1975 to 679 in 1976, or from 4 to 6 percent of the total catch.

The Soviet whaling fleets harvest three species of small whales: Minke, bottlenose, and killer. In the 1970's, the total catch of these small whales has consisted almost entirely of minke whales harvested in the Southern Hemisphere. The catch of minke whales increased suddenly in 1973 presumably because the Soviet Union increased directed whaling for this species in an attempt to offset the sharp decline in its catch of large whales. A year earlier, Japan had begun to catch

[1]During the 1976-77 and 1977-78 seasons, the Soviet Union did not harvest any fin whales.

Table 1.—Soviet, Japanese, and world catches (total[1]) of large whales, all areas, 1970-76.[2]

Year	USSR	Japan	World
1970	18,517	16,251	42,481
1971	15,014	15,794	38,771
1972	11,204	14,039	32,133
1973	14,903	11,268	32,602
1974	15,266	10,095	31,538
1975	14,456	9,450	29,179
1976[3]	11,560	3,657	16,698

[1]The total number of whales for each year is the sum of the annual catches in the North Pacific and the catches during the split-year Antarctic season, which usually lasts from December through April. This rule also applies to the following tables.
[2]Source: "International Whaling Statstics," various years.
[3]Provisional data.

Table 2.—Soviet, Japanese, and world catch (total[1]) of small whales, all areas, 1970-76.[2]

Year	USSR	Japan	World
1970	37	636	9,810
1971	51	623	8,865
1972	45	3,551	11,076
1973	3,695	2,744	14,652
1974	4,052	4,182	15,042
1975	3,543	3,976	14,258
1976[3]	3,034	3,405	NA[4]

[1]Excluding U.S. incidental kill of small marine mammals in the tuna fishery.
[2]Source: Calculated by NMFS from "International Whaling Statistics," LXXVII and LXXIX (Provisional).
[3]Provisional data.
[4]NA = Not available.

Table 3.—Russian catch of large and small whales, 1975-77[1].

Species	Season 1974-75	1975-76	1976-77[2]
Large whales			
Fin	414	88	—
Sei	1,632	505	621
Bryde's	629	679	—
Sperm	11,606	10,125	3,841
Other[3]	175	163	—
Total	14,456	11,560	4,462
Small whales			
Minke	3,500	3,017	3,950
Bottlenose	3	1	2
Killer	40	16	29
Total	3,543	3,034	3,981
Grand total	17,999	14,594	8,443

[1]Source: "International Whaling Statistics," Vol. LXXVII and LXXIX (Provisional).
[2]Total for 1976-77 Antarctic season only, including the catch north of lat. 40°S.
[3]Gray whales—aboriginal catch.

Table 4.—Soviet whaling in the Antarctic season 1975-76 and outside the Antarctic in 1976[1].

Area	Species					Total of whales	Percentage of total catch by area[3]
	Fin	Sei	Bryde's	Sperm	Others[2]		
Antarctic	88	505	—	2,683	—	3,276	28
Pelagic	(381)	(1,608)	(—)	(3,855)	(—)	(5,844)	(40)
North Pacific Ocean and Bering Sea							
Pelagic	—	—	679	3,671	—	4,350	38
	(33)	(24)	(629)	(3,750)	(—)	(4,436)	(31)
Coastal	—	—	—	—	163	163	1
	(—)	(—)	(175)	(175)	(175)	(175)	(1)
South Atlantic Ocean Pelagic[4]	—	—	—	2,124	—	2,124	18
	(—)	(—)	(—)	(2,290)	(—)	(2,290)	(16)
Indian Ocean Pelagic[4]	—	—	—	515	—	515	4
	(—)	(—)	(—)	(393)	(—)	(393)	(3)
South Pacific Pelagic[4]	—	—	—	1,132	—	1,132	10
	(—)	(—)	(—)	(1,318)	(—)	(1,318)	(9)
Total	88	505	679	10,125	163	11,560	100
	(414)	(1,632)	(629)	(11,606)	(175)	(14,456)	(100)
Percent of catch by species[3]	1	4	6	88	1	100	
	(3)	(11)	(4)	(80)	(1)	(100)	

[1]Figures in parentheses indicate previous year's totals. Source: "International Whaling Statistics," various years.
[2]Gray whales—aboriginal catch.
[3]May not add due to rounding.
[4]Antarctic pelagic expeditions on voyage to and from the Antarctic.

In the Southern Hemisphere prior to the 1972-73 season, the IWC did not regulate the harvest of individual species, but rather established an overall catch quota expressed in standard blue-whale units, e.g., 1 blue whale =2 fin =6 sei, etc. Because this system did not take into account the conditions of individual stocks, a new system of species quotas was introduced for the 1972-73 Antarctic season.

The Soviet whaling fleets in the Southern Hemisphere have generally taken all or nearly all of their quotas each year (Table 6). In the North Pacific Ocean and Bering Sea, however, the fleets have consistently harvested considerably less than permitted by the quotas (Table 7). In the 1976 season,

Table 5.—Soviet catch of large whales by areas, 1972-76[1].

Area	1972	1973	1974	1975	1976[2]
Antarctic, pelagic	5,807	5,647	7,233	5,844	3,276
North Pacific Ocean and Bering Sea					
Pelagic	2,128	5,249	4,832	4,436	4,350
Coastal[3]	182	178	183	175	163
South Atlantic Ocean[4]	1,285	2,288	1,258	2,290	2,124
Indian Ocean[4]	1,265	522	723	393	515
South Pacific Ocean[4]	537	1,019	1,037	1,318	1,132
Total	11,204	14,903	15,266	14,456	11,560

[1]Source: "International Whaling Statistics," various years.
[2]Provisional data.
[3]Gray whales—aboriginal catch.
[4]Antarctic pelagic expeditions on voyage to and from the Antarctic.

Table 6.—Soviet whale quotas and catches in the Southern Hemisphere, from 1972-73 to 1976-77[1].

Season	Q and C[2]	Species			
		Fin	Sei/Bryde's[3]	Minke	Sperm
1972-73	Q	768	1,961	No quota	7,900
	C	619	945	3,653	7,898
1973-74	Q	583	1,768	4,000	7,900
	C	583	1,768	4,000	7,900
1974-75	Q	402	1,608	3,500	7,856
	C	381	1,608	3,500	7,856
1975-76	Q	88	895	3,017	6,454
	C	88	505	3,017	6,454
1976-77	Q	0	621/0	3,950	3,841
	C[4]	0	621/0	3,950	3,841

[1]Source: "International Whaling Statistics," various years.
[2]Q=Quota; C=Catch.
[3]In 1975, the International Whaling Commission for the first time separated sei and Bryde's whales in the establishment of catch limits. Because these two species are difficult to distinguish in the field, they were previously treated together.
[4]Provisional.

large numbers of minke whales for the same reason.

In the 1970's, the Soviet Union's whale catch has generally declined. Its catch of large whales in 1976 was 38 percent less than in 1970 (Table 1). This decline, however, was not as great as that seen in the combined catch of all other countires (79 percent) or in the Japanese catch (78 percent) over the same period. The Soviet catch of small whales, like that of the Japanese, reached its maximum in 1974 with a total of 4,052 individuals and has since declined. The 1976 Soviet catch was 25 percent less than the record of 2 years before.

Although the total Soviet catch has been decreasing at a slower rate than the combined total of all other countries, the Soviets have adhered to the quotas established by the IWC[2]. Tables 6 and 7 show both the Soviet quotas and catches of individual species in the North Pacific-Bering Sea and the Southern Hemisphere.

[2]In recent years, the only objections to IWC conservation measures were by both the Soviet Union and Japan in 1973 with respect to minke whale quotas for the 1973-74 season. In previous seasons, specific quotas were not placed on minke whales. The fishing activities of both countries during the 1973-74 season resulted in the taking of almost 8,000 minke whales instead of the IWC recommendation of 5,000.

Table 7.—Soviet whale quotas and catches in the north Pacific Ocean and Bering Sea, from 1971 to 1976[1].

Season	Q and C[2]	Species		
		Fin	Sei/Bryde's[3]	Sperm
1971	Q	700	1,527	7,716
	C	190	934	5,525
1972	Q	560	1,222	6,173
	C	250	142	1,736
1973	Q	359	983	5,725
	C	161	759	4,329
1974	Q	304	983	5,725
	C	173	696	3,963
1975	Q	166	655	5,725
	C	33	653	3,750
1976	Q	0	0/681	4,752
	C[4]	0	0/679	3,671

[1]Source: "International Whaling Statistics," various years.
[2]Q=Quota; C=Catch.
[3]See note 3 in Table 6.
[4]Provisional.

the differences between North Pacific and Bering Sea quotas and catches were reduced to a certain degree.

THE FLEET

The Soviet whaling fleet in 1976 consisted of 4 motherships and 64 catcher boats (Table 8). The motherships *Vladivostok* and *Dalniy Vostok*, which are based in Vladivostok, operated in the North Pacific and Bering Sea. These vessels were constructed in the Federal Republic of Germany in the early 1960's and were commissioned in 1962 and 1963, respectively. They are built so that they can be switched over to fish processing following the conclusion of the whaling season.

The motherships *Sovetskaya Ukraina* and *Sovetskaya Rossiya* operated in the Antarctic in 1976, as they have since they were first deployed in 1959 and 1961, respectively. These motherships were constructed in Soviet shipyards and have also been equipped with fish-processing machinery. The *Sovetskaya Ukraina* is based in Il'ichevsk and the *Sovetskaya Rossiya* in Vladivostok.

A total of 31 catcher boats were used in conjunction with the *Vladivostok* and *Dalniy Vostok* during the 1976 North Pacific whaling season, and 33 boats with the *Sovetskaya Ukraina* and *Sovetskaya Rossiya* during the 1975-76 Antarctic season. Most of the catcher boats used during the various expeditions were probably of the *Mirnyy* class. About 100 of these vessels were constructed between 1956 and 1964 as part of an effort to expand and modernize the whaling fleet and to decrease the purchases of catcher boats abroad. Reportedly, many of them have been equipped to perform both whaling and fishing operations.

Two other classes of catcher boats have also been deployed on whaling expeditions. These are the *Slava* class (39.9 m, 385 GRT) and converted U.S. mine sweepers (56.4 m, 915 GRT). Presumably, these vessels are no longer in use, having been replaced by the more modern *Mirnyy*-class boats.

In the past, the Soviet whaling fleet has included as many as 7 motherships, each of which could support up to 20 catcher boats. As a result of increasing worldwide attempts to protect whales, the Soviet Union has been forced to gradually reduce the size of its fleet. In 1968, the mothership *Slava* was retired and the following year the *Aleut* was sold for scrap. In 1975, the mothership fleet was reduced to its present size, when the *Iuriy Dolgorukiy* ceased its Antarctic operations.

The number of catcher boats deployed in whaling operations has also declined. In 1973, for example, the fleet consisted of 5 motherships and about 100 catcher boats. In 1975, about 80 catcher boats were used in conjunction with the 4 remaining motherships. The following year, only 64 catcher boats were deployed.

Table 8.—The Soviet whaling fleet.

Vessel	Year built	Length (m)	Size (GRT)	Crew	Major area of operation
Motherships					
Sovetskaya Ukraina	1959	217.8	32,000	510	Antarctic
Sovetskaya Rossiya	1961	217.8	33,200	510	Antarctic
Vladivostok	1962	182.0	17,200	400	North Pacific
Dalniy Vostok	1963	182.0	17,000	400	North Pacific
Catcher Boats					
Mirnyy class	1956-64	63.6	825	30	Antarctic and North Pacific

Table 9.—Soviet production of whale oils and meal, 1970-76[1].

Year	Oils, Antarctic			Oils, Pacific			Oils, total			Meal
	Sperm	Other	Total	Sperm	Other	Total	Sperm	Other	Total	
1970	21.1	18.4	39.5	59.1	3.4	62.5	80.2	21.8	102.0	24.6
1971	18.7	18.3	37.0	47.8	2.5	52.1	66.5	20.8	87.3	21.1
1972	22.0	16.6	38.6	28.1	1.5	25.3	50.1	18.1	68.2	16.2
1973	27.8	10.7	38.5	32.2	1.7	33.9	60.0	12.4	72.4	17.3
1974	29.8	12.6	42.4	30.0	1.5	31.5	59.8	14.1	73.9	18.3
1975	24.2	10.3	34.5	35.0	0.8	35.8	59.2	11.1	70.3	17.1
1976	18.6	4.6	23.2	33.4	0.8	34.2	52.0	5.4	57.4	11.4

[1]Source: "FAO Yearbook of Fishery Statistics: Fishery Commodities," various years.

Unless otherwise noted, material in this section is from the Foreign Fishery Information Releases (FFIR) compiled by Sunee C. Sonu, Foreign Reporting Branch, Fishery Development Division, Southwest Region, National Marine Fiseries Service, NOAA, Terminal Island, CA 90731, or the International Fishery Releases (IFR) or Language Services Daily (LSD) reports produced by the Office of International Fisheries, National Marine Fisheries Service, NOAA, Washington, DC 20235.

WHALE UTILIZATION

The Soviet Union produces whale oil, whale and bone meal, whale meat, blubber, ventral grooves, whale liver, vitamin A, and other products from its annual whale catch. In terms of quantity, whale oils are the single most important commodity.

The Soviet production of whale oils has decreased at about the same rate as the total catch during the 1970's (Table 9). Total oil production in 1976 was 44 percent less than in 1970, compared with a corresponding 38 percent decrease in the total catch of large whales. The production of sperm whale oil, which has been making up an increasing percentage of the total oil production, has decreased less than the production of oils from other whales: 35 percent as compared with 75 percent between 1970 and 1976. In 1970, sperm whale oil accounted for 79 percent of the total oil production of 102,000 metric tons (t); by 1976 sperm whale oil production had risen to over 90 percent of the total of 57,400 t.

The Soviet production of whale meal, like that of oils, has decreased during the 1970's. Meal production went from 24,600 t in 1970 to 11,400 t in 1976, a 54 percent decrease.

The Soviet whaling industry is also engaged in the production of whale

meat, whale liver, blubber, ventral grooves, vitamin preparations, and other products. Complete statistics on the annual Soviet output of these products, however, are not available. Table 10 shows the Soviet production of whale by-products from the North Pacific pelagic fishery for 1970-75. Similar data does not exist for the Antarctic pelagic fishery.

Statistics on the per capita consumption and industrial uses of whale products in the Soviet Union are not published by the Soviet Government. Though some Soviet nationalities in the Far East do include whale meat in their diets, the majority of Soviet citizens are reportedly not fond of it. Large quantities of the whale meat produced in the Soviet Union are exported to Japan. Some of the whale meat that is retained domestically is used in the production of fish sausages or boiled for use as feed for fur-bearing animals, such as mink.

FOREIGN TRADE

Soviet trade in whale products is dominated almost exclusively by exports; there is little or no import activity. The two major export products are whale oils and meats. Certain other whale products are also exported but they are not listed separately in Soviet trade statistics. For example, exports of vitamins extracted from whale liver are included in the general category of "medicinal oils from marine products," thus making it impossible to determine the exact quantity of vitamins traded.

Soviet exports of whale oils have declined tremendously in the 1970's. In 1970, oil exports totaled 34,100 t; by 1976, only 1,900 t of oil were exported, a decrease of over 94 percent (Table 11). The value of these exports declined by more than 93 percent over the same period. Soviet exports of whale oils were greatest in the 1960's, when they reached a peak in 1966 at 70,500 t.

Soviet exports of whale oils to various countries in the 1970's are shown in Table 12. As is evident from the table, foreign buyers of Soviet whale oils have become fewer and fewer in number. In 1976, the only major importer of Soviet whale oil was Czechoslovakia, which purchased 800 t. The Netherlands, which at one time imported large quantities of Soviet whale oil, has turned to other sources of supply, Japan being among them. In 1976, the Soviet Union exported 3.3 percent of its total oil production; in 1970, over 33 percent of its total production was exported.

In contrast to the general downward trends noted in all sectors of the Soviet whaling industry thus far, Soviet exports of whale meat increased between 1970 and 1976 (Table 13). These exports rose by 33 percent during that period, increasing from 13,500 t to 18,000 t. Japan, which has been the primary importer of Soviet whale meat in the 1970's, is now the sole importer. Japanese imports increased from 7,500 t, or 56 percent of total Soviet whale meat exports, in 1970 to 18,000 t, or 100 percent of Soviet exports, in 1976. The sudden increase in Japanese imports in 1973 coincided with the equally sudden increase in the Soviet catch of minke whales, the meat of which is commercially valuable for human consumption. In terms of value, Japanese imports of Soviet whale meat increased by nearly 680 percent between 1970 and 1976, compared with a 240 percent increase in quantity. (Source: IFR-78/93.)

Table 10.—Soviet production of whale by-products (in metric tons) from the North Pacific pelagic fishery, 1970-75[1].

Year	Meal	Liver	Meat, blubber, ventral grooves	Other	Vitamin A[2]
1970	11,737	—	8,254	362	10.2
1971	8,892	—	5,472	495	10.1
1972	3,065	—	3,634	312	3.1
1973	4,227	108	4,613	508	3.7
1974	3,763	—	4,905	53	4.0
1975	3,364	—	4,171	267	3.7

[1]Source: "International Whaling Statistics," various years.
[2]Data is listed in trillions of units.

Table 11.—Soviet exports of whale oils, 1970-76[1].

Year	Quantity (1,000 metric tons)	Value: 1,000 Rubles	Value: 1,000 US$
1970	34.1	7,815	8,683
1971	14.2	3,399	3,777
1972	16.0	3,245	3,946
1973	4.3	899	1,215
1974	4.2	888	1,197
1975	4.0	946	1,307
1976	1.9	432	572

[1]Source: "FAO Yearbook of Fishery Statistics: Fishery Commodities," various years.

Table 12.—Soviet exports of whale oils by country, 1970-76[1].

Country	1970	1971	1972	1973	1974	1975	1976
	1,000 metric tons						
Czechoslovakia	3.2	2.0	4.9	2.1	2.1	2.0	0.8
German Dem. Republic	3.0	1.1	—	—	—	—	—
Hungary	1.2	—	—	—	—	—	—
Netherlands	21.5	8.7	8.4	—	—	—	—
United Kingdom	4.0	—	—	—	—	—	—
Other	1.2	2.4	2.7	2.2	2.1	2.0	1.1
Total	34.1	14.2	16.0	4.3	4.2	4.0	1.9

[1]Source: "Vneshnyaya Torgovlya SSSR," various years.

Table 13.—Soviet exports of whale meat, 1970-76[1].

Year	To all countries: Quantity 1,000 metric tons	To all countries: Value[2] 1,000 Rubles	To all countries: Value[2] 1,000 US$	To Japan: Quantity (1,000 metric tons)	To Japan: Value[2] 1,000 Rubles	To Japan: Value[2] 1,000 US$	Exports to Japan as percent of total
1970	13.5	2,697	2,854	7.5	1,505	1,593	56
1971	11.5	2,623	2,914	8.0	1,847	2,052	70
1972	10.0	2,068	2,516	6.7	1,411	1,716	67
1973	11.7	2,687	3,631	11.7	2,687	3,631	100
1974	17.2	5,005	6,745	17.2	5,005	6,745	100
1975	15.1	4,061	5,609	15.1	4,061	5,609	100
1976	18.0	8,135	10,775	18.0	8,135	10,775	100

[1]Source: "Vneshnyaya Torgovlya SSSR," various years.
[2]US$ values calculated from annual exchange rates.

Hard Winters Claim Chesapeake Croakers

The virtual loss of two successive croaker year classes in lower Chesapeake Bay was confirmed by trawl surveys last summer of the Virginia Institute of Marine Science (VIMS). The loss is attributed to the very cold winters of 1976-1977 and 1977-1978, the Institute reports.

In announcing the survey findings, VIMS director William J. Hargis, Jr. indicated that the croaker year class losses will likely diminish the commercial and recreational croaker catches more noticeably next spring and summer. A mild 1978-1979 winter is needed to avert a more serious croaker decline such as occurrred following the freezing winters of the 1918, 1958, and 1964 periods.

The lack of young croakers in last summer's trawl survey had been expected by VIMS fishery scientists because only dead juveniles had been taken in the 1977 and 1978 winter trawl samples. Croakers spawn at sea and the very small juveniles enter the estuary nursery areas in late fall, winter, and very early spring at a stage in ther lives in which they are extremely sensitive to low water temperatures. Under normal winter water temperature conditions, juveniles taken in the VIMS sampling program would be alive and, had they survived for about 2 years, would form the basis for the commercial and recreational catches later.

"Our average summer catch of young croakers from the 1977 spawn was less than one fish per tow," said John Merriner, who heads VIMS finfish studies. "This compares with more than 15 fish per tow during the summer surveys preceding the 1976 and 1977 winter freezes."

Water temperatures of 32.5°F (0.3°C) killed young croakers in laboratory studies, according to Merriner. Also, their swimming ability was slowed by temperatures of 36.5°F (2.5°C) suggesting that they are placed at the mercy of river currents when low temperatures set in.

Large numbers of croakers have been caught in Chesapeake Bay for several years, following very poor catches in the 1960's. Those caught in 1978 were mostly older and larger fish with a noticeable absence of small ones that should have been present from the 1976 year class.

The VIMS scientists feel that a mild 1978-1979 winter should support good survival of the 1978 year class and provide a return of croaker numbers by 1979. However, a third successive freezing winter may cause a more severe downward trend, according to Merriner.

TEXAS FISH KILLS LAID TO WEATHER

Hot, dry weather was blamed for two major fish kills reported on the Texas Gulf Coast in mid-summer, according to the Texas Parks and Wildlife Department. The weather apparently caused excessive evaporation and higher salinity levels at Sabine Lake near Port Arthur where an estimated 9,262 pounds of redfish died in the south spoil disposal compound on 7 July. The total kill amounted to about 100,000 to 125,000 fish, but was not complete, as some fish were observed alive after the kill.

Another fish kill occurred later that month in a cove in Baffin Bay, where about 5,000-plus pounds of speckled trout succumbed to low oxygen and high salinity levels. High salinities last summer were noted in Texas' Upper and Lower Laguna Madre areas, where most commercial crabbers had removed their crab traps to move them to the Trinity Bay area where salinity levels were lower.

WASHED SHELL COULD BOOST CAROLINA SHELLFISH CROP

Oyster mounds that accumulate naturally in South Carolina's coastal area could help boost the state's shellfish crop, according to a state report. A survey by the South Carolina Wildlife and Marine Resources Department located about 370,000 cubic yards of exposed oyster shell called "washed shell" because it is washed into mounds by wave action and boat wakes. Additional washed shell material may occur below the low tide mark but this area was not surveyed.

According to shellfish biologist William Anderson of the department's Office of Conservation, Management and Marketing, washed shell planted on oyster beds makes an ideal substrate for the attachment of free-swimming oyster larvae or spat. Anderson also noted that while washed shell has advantages over freshly shucked, or "green" shell for providing cultch material for oyster spat, its use for this purpose has not been previously attempted on a large scale in South Carolina.

Oyster spat attach to washed shell at lower densities which allows them more area to grow to a larger size, the biologist noted, while oyster spat often attach to green shell at such high densities that their growth is hampered. Small oysters have little commercial value. Commercial oyster lease holders are required to plant 65 South Carolina bushels of shell per leased acre each year, but sufficient quantities of green shell are not always available for planting. Washed shell could serve to supplement supplies for the required planting operations, Anderson said.

Washed shell also could be used to upgrade and improve some of the areas available for public shellfish harvesting. In addition, washed shell could be used as a substrate for establishing hard clam beds for both commercial and recre-

ational utilization. Because washed shell is light in weight and possibly could be washed away before oyster spat could attach to it, Anderson said that washed shell might have to be topped with a layer of heavier green shell or planted in areas which are not subject to wave action.

Although the recent survey located an extensive washed shell resource, Anderson said that the renewal rate once the shell is removed is not known. "Once we learn more about washed shell and how it can best be utilized, then washed shell could become another valuable, renewable marine resource," Anderson said.

Maryland Seeks Striped Bass Improvements

A Maryland committee of commercial watermen, sport fishermen, biologists, and charter boat skippers are meeting regularly in an attempt to find out why rockfish, or striped bass, populations appear to have been dropping and to recommend steps to help turn the situation around. The Citizens Advisory Committee on Striped Bass Management was formed by the Maryland Department of Natural Resources after a regional workshop in September 1977. The panel's work intensified after a spawning season restriction was imposed last spring on taking rockfish in certain waters.

The committee has been meeting since late March. It has heard from scientists including representatives of DNR's Fisheries Administration, the University of Maryland's Center for Estuarine and Environmental Studies, and sport and commercial fishermen's organizations. The committee is eager to hear from as many segments of the public as possible with regard to the rockfish situation.

The committee also has input into the deliberations of a regional citizens' advisory unit comprised of representatives of Atlantic coastal states from Maine to North Carolina. Goal of the regional bodies is development of a management plan for striped bass similar to successful State-Federal plans for northern shrimp, American lobster, and surf clams.

While the Maryland Advisory Committee has yet to adopt any specific recommendations, it has addressed in depth these general issues: 1) Regulations regarding the taking of rockfish including seasons, types of permissable equipment, size limits, and licensing; 2) research needs; 3) a striped bass hatchery; 4) water quality; 5) aquatic grasses; 6) possible increased financing for striped bass management and research; and 7) law enforcement.

South Carolina Gives Sea Turtles Extra Protection

More protection has been granted the loggerhead sea turtle in South Carolina waters by the State legislature acting on a regulation written by the state wildlife department that classifies the turtle in a "threatened" status. The regulation provides for a fine of up to $500 and 6 months in jail for each violation of the regulation which would include harassment, hunting, killing, capturing, possession, or the selling or shipping of any turtle, part, nest or egg.

Shrimpers who incidentally catch turtles in their nets will not be prosecuted, although biologists with the South Carolina Wildlife and Marine Resources Department are encouraging shrimpers to make every effort to return turtles to the water alive, said a department spokesman. The protection is provided through the South Carolina Nongame and Endangered Species Conservation Act of 1974. While the State act has no provision for threatened status, as written in the regulation protection is now provided the turtle which roughly parallels the Federal designation of "threatened."

ALABAMA SETS NEW LIMITS ON THREE SALTWATER FISH

By a regulation issued on 8 August, the Marine Resources Division of the Alabama Department of Conservation and Natural Resources established creel and size limits on speckled trout, redfish, and red snapper caught by recreational fishermen in Alabama waters and on these species caught outside of Alabama waters but landed in Alabama.

Limits were set at 50 speckled trout, 25 redfish, and 25 red snapper per day. Fishermen returning from trips of two or more consecutive days may have in their possession not more than twice the daily catch limit. Minimum sizes are 12 inches for speckled trout, 8 inches for red snapper and 14 inches for redfish, but no more than two redfish more than 36 inches in length may be retained.

These restrictions were enacted in an attempt to halt the decline in the numbers of these species, particularly speckled trout and red snapper, according to the Department of Conservation. Alabama was the last Gulf Coast state to enact such regulations on these two species.

Washington State Eyes Manila Clam Developments

The Manila clam, introduced to the U.S. West Coast by accident with imports of Japanese oyster seed, is good eating. Supply does not equal demand, however, and for the past 5 years the University of Washington College of Fisheries (with Washington Sea Grant support) and the state's Departments of Fisheries and Natural Resources have been focusing on ways to maintain already established clam populations and to develop new ones.

Seeding of beaches with hatchery-spawned clams shows promise of doing this, but several factors must be taken into account. The beach, for example, should be gradually sloping with natural or artificial protection, according to researchers. The ideal substrate is gravel, coarse sand, a certain amount of mud or clay, and some shell. Planting should be done in the spring so that growth can start before the seed is exposed to cold temperatures, storms, or predation. Permission from the Washington Department of Fisheries is required for planting or transplanting seed clam, and other state agencies must be contacted if the substrate is to be altered in any way.

New NMFS Scientific Reports Published

The publications listed below may be obtained from either the Superintendent of Documents (address given at end of title paragraph on affected publications) or from D822, User Services Branch, Environmental Science Information Center, NOAA, Rockville, MD 20852. Writing to the agency prior to ordering is advisable to determine availability and price, where appropriate (prices may change and prepayment is required).

NOAA Technical Report NMFS SSRF-717. Colton, John B., Jr., and Ruth R. Byron. **"Gulf of Maine-Georges Bank ichthyoplankton collected on ICNAF larval herring surveys September 1971-February 1975."** November 1977. 35 p.

ABSTRACT

The families, genera, and species of all larval fishes are tabulated and the abundance, length frequencies, and distribution of 12 species and 2 families are summarized utilizing data collected on 8 ichthyoplankton surveys of the Gulf of Maine-Georges Bank area. The segregation of coastal and oceanic species north and south of the coastal/slope water boundary during December is evidenced in a comparison of the distribution of upper 100-m integrated temperature and Atlantic herring, Myctophidae, and Paralepididae larvae. All larval barracudinas and lanternfishes occurred in areas where the integrated temperature was above 11° and 13°C, respectively. Ninety-one percent of positive larval herring tows were in areas where the integrated temperature was below 13°C.

NOAA Technical Report NMFS Circular 406. Ho, Ju-Shey. **"Marine flora and fauna of the northeastern United States. Copepoda: Lernaeopodidae and Sphyriidae."** December 1977. 14 p.

ABSTRACT

This manual includes an introduction to the general biology, a glossary, an illustrated key, an annotated systematic list, a selected bibliography, and an index to the 16 species of lernaeopodoid Copepoda parasitic on marine fishes of the northeastern United States.

NOAA Technical Report NMFS SSRF-718. Squire, James L., Jr. **"Surface currents as determined by drift card releases over the continental shelf off central and southern California."** December 1977. 12 p.

ABSTRACT

During March 1964 through February 1966, 8,320 plastic drift cards were released at selected points from an aircraft to measure surface current drift over two areas: From the coast to about 48 n.mi. off central California between Point Arena and Point Sur; and from the coast to about 90 n.mi. off southern California between Point Arguello and Punta Salsipuedes, Baja California, Mexico. The recovery rate was 3.5 percent in the central area and 5.7 percent in the southern area. An average 79.4 percent of the recoveries were found within 2 weeks following the date of release. Results lend support to studies concluded by earlier investigators. The distribution of the direction from which drift cards were returned increased the evidence for the presence of an eddy off the coast between San Francisco and Monterey Bay during May through July, and of the large gyre and associated southern California countercurrent south of Point Conception during April through August and to a lesser extent in October and December.

NOAA Technical Report NMFS Circular 407. Williams, Austin B., and Roland L. Wigley. **"Distribution of decapod Crustacea off northeastern United States based on specimens at the Northeast Fisheries Center, Woods Hole, Massachusetts."** December 1977. 44 p.

ABSTRACT

Distributional and environmental summaries are given in an annotated checklist, supplemented by charts, graphs, and tables, for 131 species of marine decapod Crustacea found between the Gulf of Maine and near the mouth of Chesapeake Bay. The geographical area lies mainly on the continental shelf with some extension beyond this to submarine canyons and the upper continental slope. The area lies within two climate zones which influence the distribution of decapods, cold temperate in the north and mild temperate in the south. The list is thought to be reasonably complete for benthic but not for pelagic species. Benthic samples collected with several types of gear by vessels of the National Marine Fisheries Service (NMFS) during the past 25 years provided the records that are charted. Data from samples on which this report is based are stored in computer files, and selected specimens are preserved in collections at the NMFS Northeast Fisheries Center, Woods Hole, Mass.

NOAA Technical Report NMFS Circular 408. Shomura, Richard S. (editor). **"Collection of tuna baitfish papers."** December 1977. 167 p.

ABSTRACT

An invitational workshop on tuna baitfish problems, cosponsored by the National Marine Fisheries Service and the University of Hawaii Sea Grant College, was held at the Honolulu Laboratory, Southwest

Fisheries Center, NMFS, 4-6 June 1974. Issues addressed dealt with the problem of securing adequate supplies of bait to support the development or expansion of skipjack tuna, *Katsuwonus pelamis*, fishing in the central and western tropical Pacific Ocean. Three workshop sessions focused attention on: 1) Natural stocks of baitfish, 2) culture of suitable baitfish species, and 3) transportation and holding bait and substitute baits. Sessions were preceded by a general review of baitfish problems and a discussion on the criteria for a good baitfish species. Twenty papers from this workshop are presented in this volume.

NOAA Technical Report NMFS SSRF-719. Thompson, Perry A., Jr., and Thomas D. Leming. **"Seasonal description of winds and surface and bottom salinities and temperatures in the northern Gulf of Mexico, October 1972 to January 1976."** February 1978. 44 p.

ABSTRACT

Seasonal surface and bottom salinities and temperatures in the northern Gulf of Mexcio are described. The area surveyed was between Mobile Bay, Ala. (long. 88°00′W), and Atchafalaya Bay, La. (long. 91°30′W), from 5 to 50 fathoms (9 to 91 m).

NOAA Technical Report NMFS Circular 409. Ho, Ju-Shey. **"Marine flora and fauna of the northeastern United States. Copepoda: Cyclopoids parasitic on fishes."** February 1978. 12 p.

ABSTRACT

This manual includes an introduction on the general biology, an illustrated key, an annotated systematic list, a selected bibliography, and an index to the 19 species of cyclopoid copepods parasitic on marine fishes of the northeastern United States.

NOAA Technical Report NMFS SSRF-723. Mattson, Chester R., and Bruce L. Wing. **"Ichthyoplankton composition and plankton volumes from inland coastal waters of southeastern Alaska, April-November 1972."** April 1978. 11 p.

ABSTRACT

Eighteen families of fish were represented in 119 plankton samples taken on monthly cruises from April to November 1972 in southeastern Alaska. Fifteen kinds of larval fish were identified to species. Abundance of larval fish, fish eggs, and total plankton biomass peaked in May and declined through the summer. Walleye pollock (family Gadidae) were the most abundant larvae in May and June and were more concentrated in large channels than in small bays. Osmeridae and Bathylagidae were the second and third most abundantly represented families; peak abundance for both was in June and July. Other families with distinct peaks in abundance were Agonidae and Ammodytidae in May; Cottidae, Cyclopteridae, Stichaeidae, and Pleuronectidae in June; and Scorpaenidae in July. Small numbers of Bathymasteridae were present from May through July. Myctophidae, Zoarcidae, and Hexagrammidae did not show distinct changes in seasonal abundance. Clupeidae, Gasterosteidae, Pholidae, and Ptilichthyidae were too rare in the catches to exhibit seasonal abundance. Calanoid copepods and phytoplankton made up most of the plankton retained by 0.333-mm mesh nets.

NOAA Technical Report NMFS SSRF-722. Nicholson, William R. **"Gulf menhaden, *Brevoortia patronus*, purse seine fishery: Catch, fishing activity, and age and size composition, 1964-73."** March 1978. 8 p.

ABSTRACT

The menhaden purse seine fishery in the Gulf of Mexico, primarily for Gulf menhaden, *Brevoortia patronus*, extends from about early April to early October. From 1964 to 1973 the catch fluctuated between 317,000 and 728,000 t and the number of vessels ranged from 65 to 82. Larger and faster refrigerated vessels replaced most of the smaller nonrefrigerated vessels and modern methods of fishing were adopted. Population levels were high and there were no large fluctuations in year class abundance. Age-1 and -2 fish supplied from 95 to 99 percent of the catch by weight. Over 97 percent of the fish were between 120 and 225 mm fork length. The mean age and size generally were slightly greater in the center of the fishery (central and eastern Louisiana) than in the eastern (Mississippi) and western areas (western Louisiana and Texas). Mean age decreased as the season progressed.

Atlas Examines Heat Budgets of Tropical Atlantic and Pacific

Publication of "The heat budget of the tropical Atlantic and eastern Pacific Oceans" has been announced by The University of Wisconsin Press. Authors Stefan Hastenrath, Professor of Meteorology, and Peter Lamb, Project Associate, are both with the Department of Meteorology, University of Wisconsin-Madison.

A sequel to the "Climatic atlas of the tropical Atlantic and eastern Pacific Oceans", published in January 1977, the latest volume is also based on a 60-year (1911-70) record of 7,000,000 sets of ship observations processed by one degree square areas. Monthly and annual maps are presented of net surface shortwave, net surface longwave, and net surface all-wave radiation; sensible and latent heat flux; evaporation; and net oceanic gain. The atlas also discusses the large- and small-scale heat budget features associated with atmospheric-ocean conditions, such as the near-equatorial convergence and cloudiness bands, cold and warm ocean currents, and coastal upwelling.

Spiral bound, this 9- × 18-inch, 104-page volume is available from The University of Wisconsin Press, Box 1379, Madison, WI 53701 for $35.00.

Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 6, "A List of Common and Scientific Names of Fishes from the United States and Canada," third edition, 1970. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

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Title the list of references "Literature Citations" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, the year and month and volume and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

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Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8- × 10- inches, sharply focused glossies of strong contrast. Potential cover photos are welcome but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 1107 N.E. 45th Street, Room 450, Seattle, WA 98105.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 100 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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